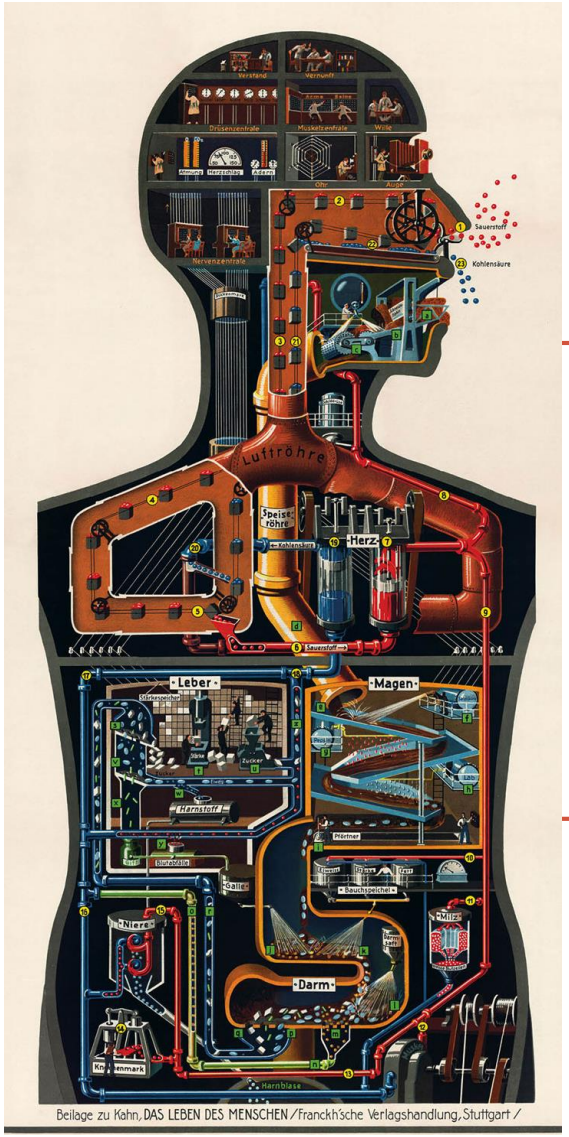


Fritz Kahn (1888 – 1968)

ΕΜΒΙΟΜΗΧΑΝΙΚΗ

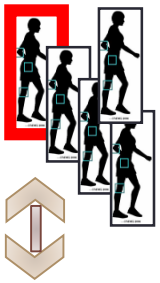
BIOMECHANICS

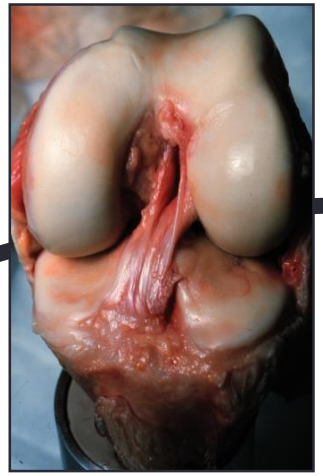
#1: ΕΙΣΑΓΩΓΗ / Introduction

9th semester
Dept of Mechanical Engineering, NTUA

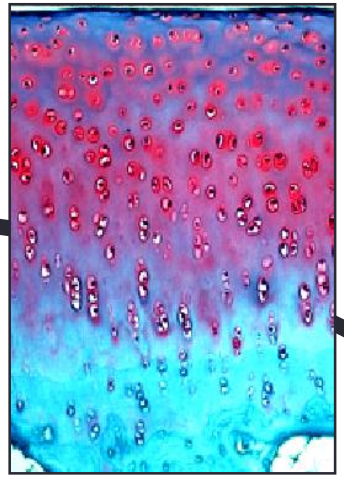
Instructors:
Prof. Leonidas Alexopoulos
Dr Michael Neidlin

AIM OF THE COURSE



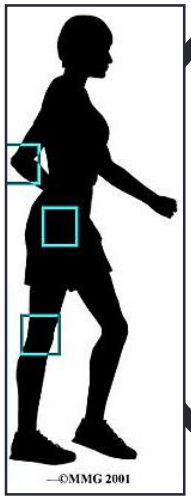


Organ (10^{-2} m)



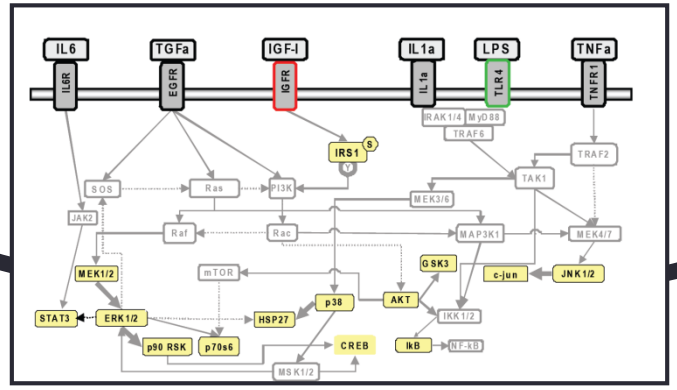
Tissue (10^{-3} m)

Different levels of Modeling in Bioengineering

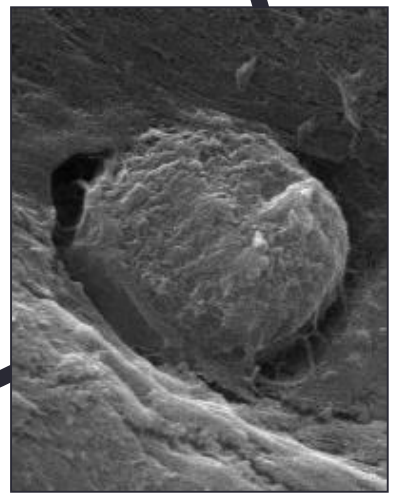


Patient (10^{0} m)

Understand the mechanics of the human body and its components



Sub-cell (10^{-9} m)

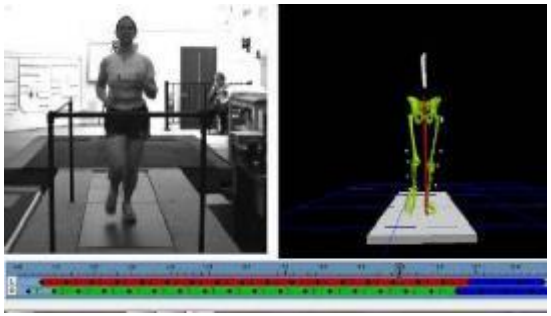


Cell (10^{-5} m)

Procedure

1. Understand the **anatomy** and physiology (clinician)
2. Understand the **function** (engineer)
3. Present problems (clinical) and **solutions** (engineer)

Learn about (some) methods in biomechanics
and biomedical engineering



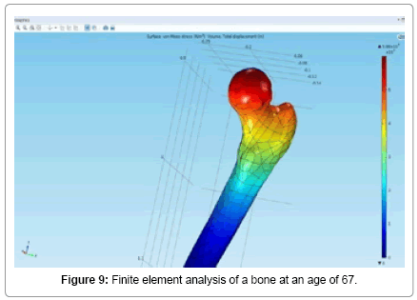


Figure 9: Finite element analysis of a bone at an age of 67.

Bioengineering courses at ME / NTUA

7ο Εξάμηνο	8ο Εξάμηνο	9ο Εξάμηνο
**** Εισαγωγή στην Βιολογική Μηχανική** **BIOLOGICAL ENGINEERING** Κος Αλεξόπουλος	**** Ανάλυση και σχεδιασμός βιοϊατρικών συστημάτων** **MEDICAL DEVICES** Κος Αλεξόπουλος	**Εμβιομηχανική** **BIOMECHANICS** Κος Αλεξόπουλος
	Απεικονίσεις και Θεραπευτικές Ακτινοβολήσεις Βιοϊατρικής Τεχνολογίας **MEDICAL IMAGING** Κος Αναγνωστάκης	**Βιορευστομηχανική** **BIOFLUID MECHANICS** Κος Τσαγγάρης

+ Innovation Course

** Νέα Μαθήματα από 2016

Bioengineering courses at ME / NTUA

Αποκτάτε βασικές Γνώσεις Βιοιατρικής και Βιολογίας (όλες οι κατευθύνσεις)

Σχεδιαζετε Βιοιατρικές συσκευές (concept, market analysis, business plan, design) (κατασκευαστικός / παραγωγής / καινοτομία)

Εφαρμογές σε Biomechanics (κατασκευαστές)

7ο Εξάμηνο	8ο Εξάμηνο	9ο Εξάμηνο
**** Εισαγωγή στην Βιολογική Μηχανική** **BIOLOGICAL ENGINEERING** Κος Αλεξόπουλος	**** Ανάλυση και σχεδιασμός βιοϊατρικών συστημάτων** **MEDICAL DEVICES** Κος Αλεξόπουλος	**Εμβιομηχανική** **BIOMECHANICS** Κος Αλεξόπουλος
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Εφαρμογές σε απεικονίσεις

Εφαρμογές σε Μηχανική ρευστών

Syllabus

Class	Description	
1ο	Introduction	
2ο	Anatomy 101	
3ο	Tissue and Joint Mechanics	
4ο	Numerical and Experimental Methods in Biomechanics	
5ο	Practical course : Implant fitting study I	
6ο	Practical course : Implant fitting study II	
7ο	Tissue Engineering	
8ο	Cell Mechanics	
9ο	Practical course: FEM Hip Implant Study	
10ο	Practical course: FEM Hip Implant Study	

Course Instructors

Prof. Leonidas Alexopoulos, PhD

leo@mail.ntua.gr

Tel: 210 7721666

Dr. Michael Neidlin

neidlin@central.ntua.gr

Tel: 210 7721516

Exams

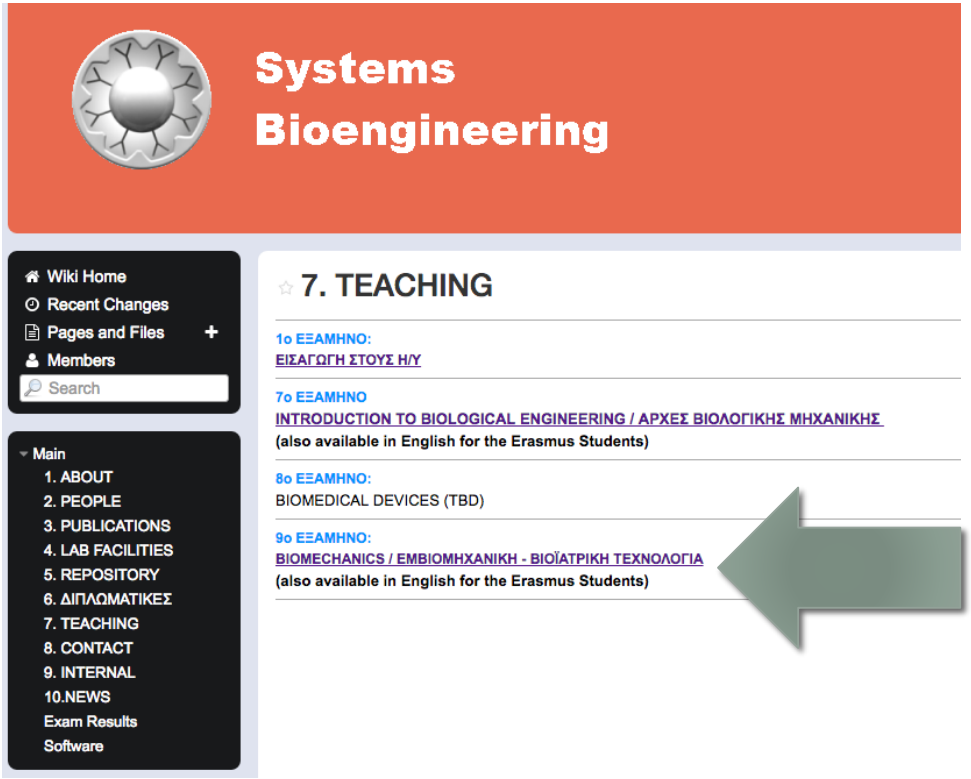
TBD

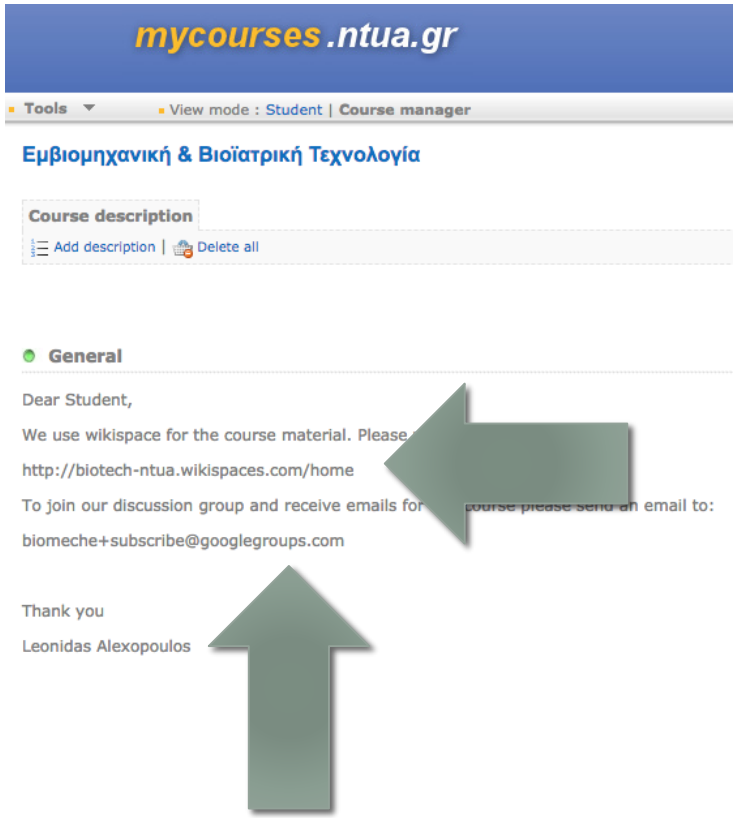
- We will have mandatory homeworks during the semester

- If „significant“ work has been carried out, we have no exams (similar to the „Medical Device“ course)

Webpage:

- http://biotech-ntua.wikispaces.com/home





Webpage:

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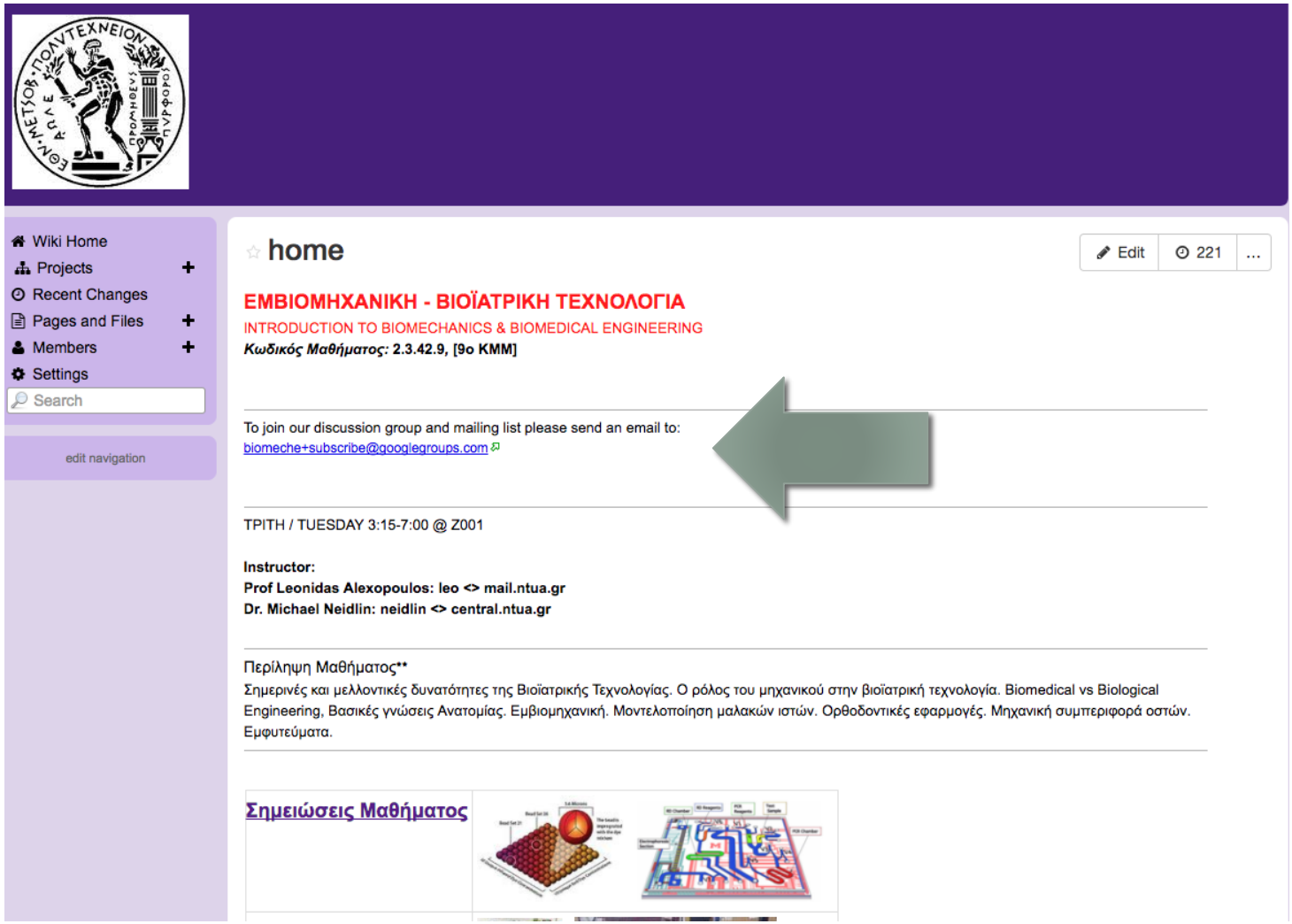
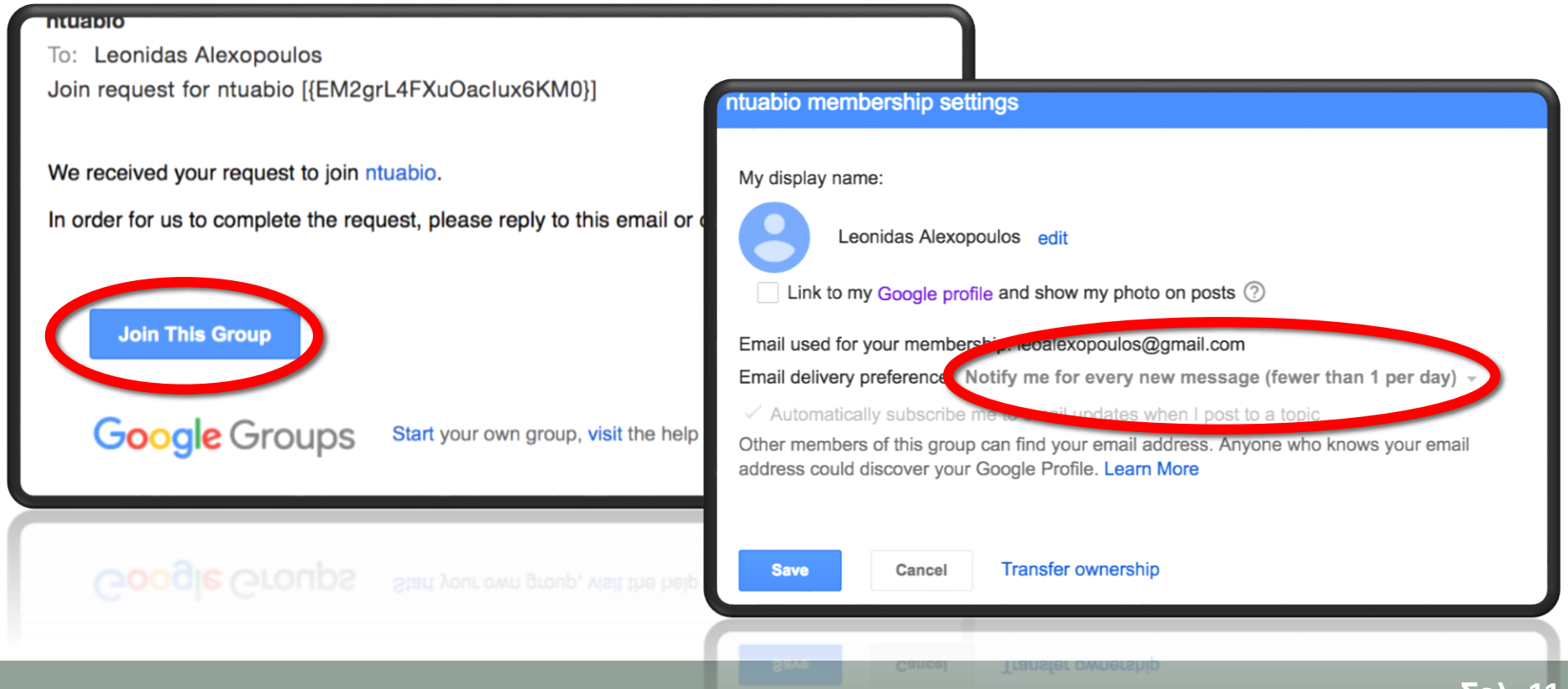


Action item: Subscribe to mailing list

Για εγγραφή στο μάθημα παρακαλώ στείλτε e-mail στο:

biomeche+subscribe@googlegroups.com



Today

1. Introduction to Bioengineering

   Revision of the 7th & 8th semester course

2. Introduction to Biomechanics

Biomedical Engineering

Anything that combines—in any proportion—biology or medicine on the one hand and one of the engineering disciplines on the other.
(Engineering in Medicine and Biology Society)

Οτιδήποτε συνδυάζει την επιστήμη του μηχανικού με εφαρμογές σε Ιατρική, Υγεία και Βιολογία

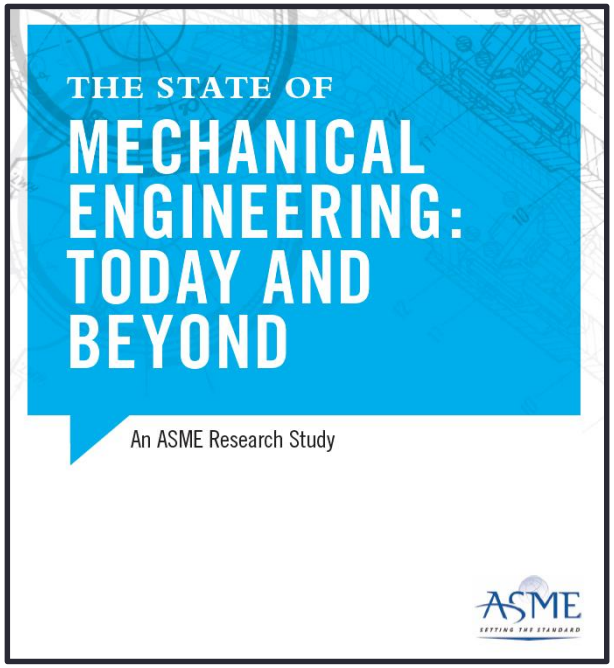
- Βιοϊατρική Μηχανική
- Ιατροτεχνολογική Μηχανική
- Βιολογική Μηχανική
- Εμβιομηχανική
- Υπολογιστική Βιολογία
- Βιοτεχνολογία

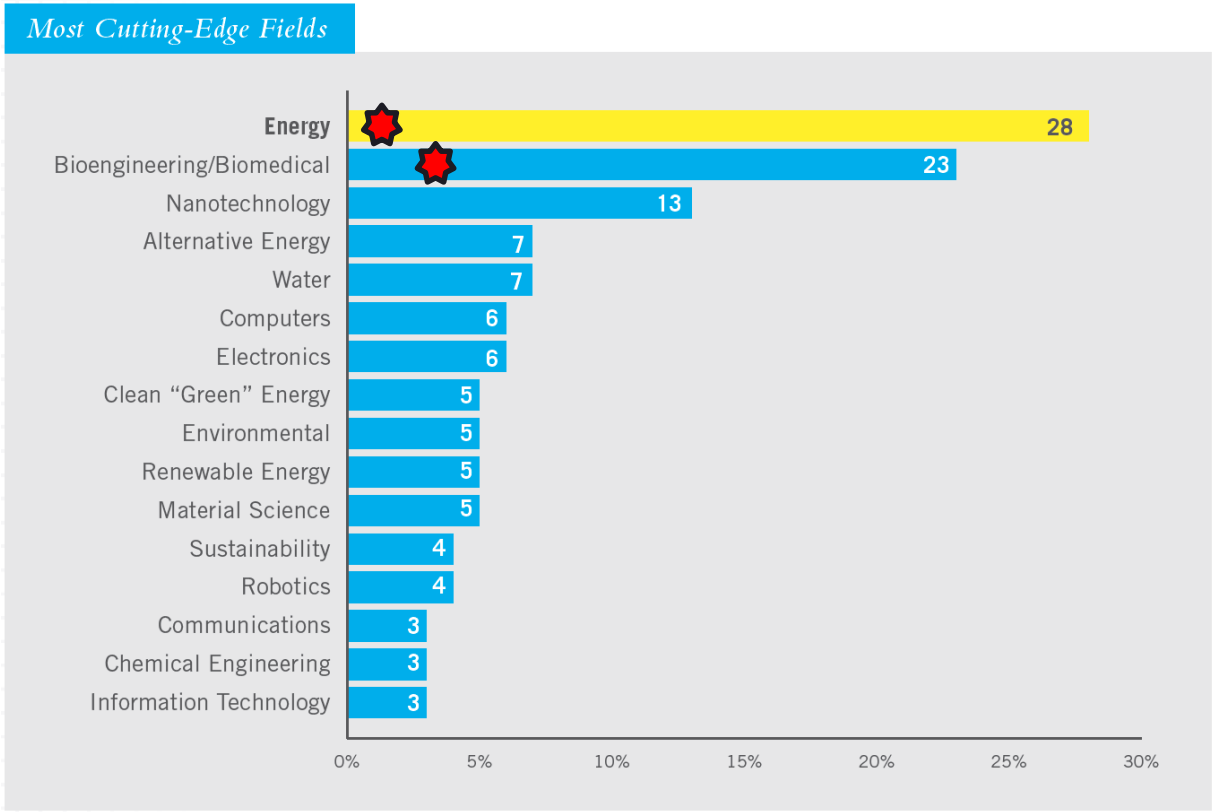
Σχολές & Τμήματα

- Biomedical Engineering (BME)
- Bioengineering
- Biological Engineering
- Biotechnology
- Medical Engineering
- Computational Biology
- Systems Biology
- Systems Pharmacology
- Network Medicine

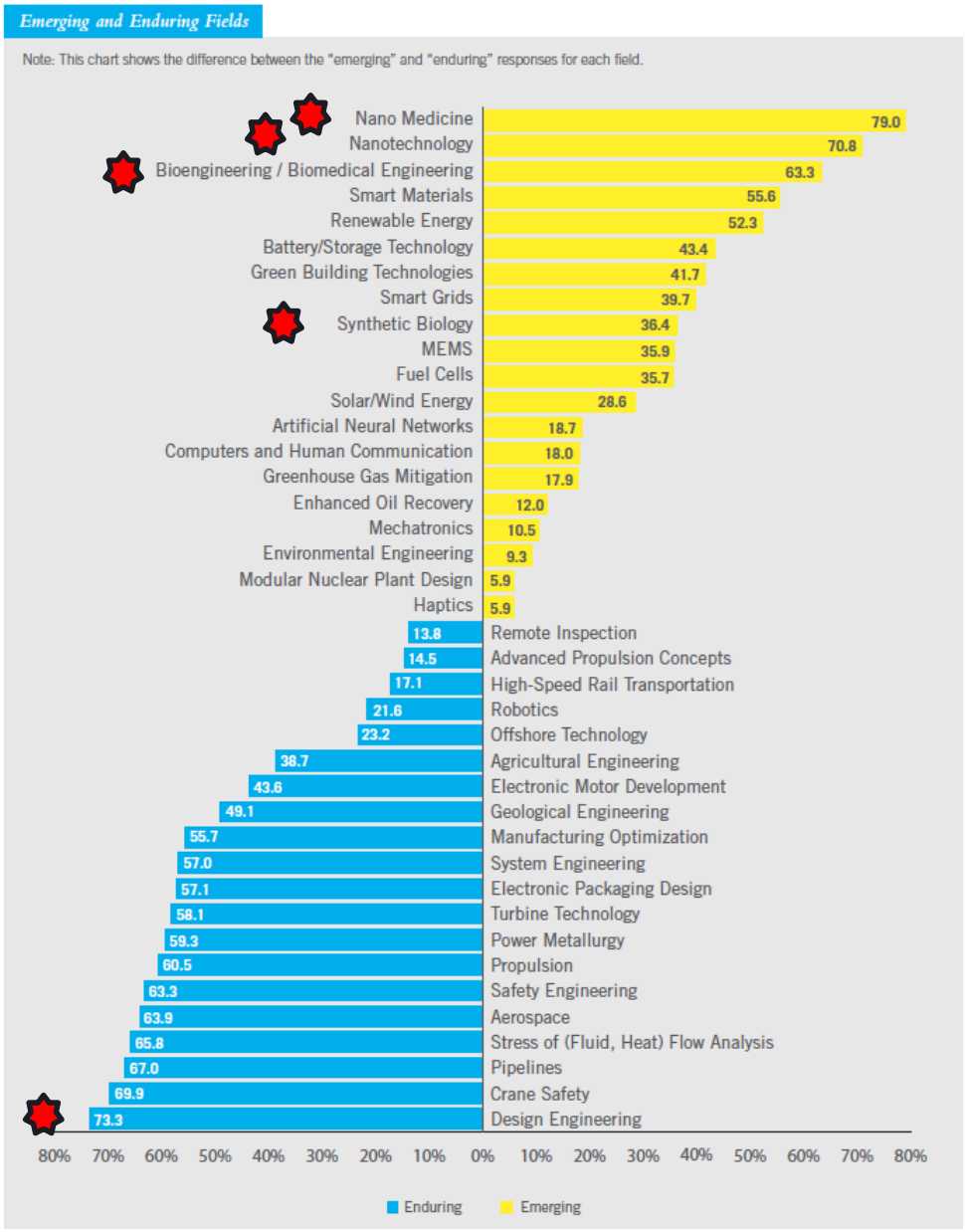
Biomedical Engineering: One of the faster growing disciplines

Πηγή: ASME





Biomedical Engineering: One of the faster growing disciplines



Πηγή: ASME

Related industry:

Medical Device

Ιατροτεχνολογικά Προϊόντα

~$400 billion in 2015
CAGR: 6%

Digital Health

Ψηφιακή Υγεία

~$80 billion in 2015
CAGR: 21%

BioPharma

Φαρμακευτικά Προϊόντα

~$1000+ billion in 2015
CAGR: 3-6%

Πηγή:
Παρουσίαση από το 2016 «MIT Enterprise Forum Technologies that Matter Series Life Sciences»
Elias Papatheodorou, Aris Constantinides

Medical Device

> 5000 types of medical devices (FDA list)!

Medical device (brief):

An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose. Typically, the purpose of a medical device is not achieved by pharmacological, immunological or metabolic means.

Medical equipment:

Medical devices requiring calibration, maintenance, repair, user training and decommissioning – activities usually managed by engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following disease or injury

Digital Health = **Medical Dev + IT + Informatics**

(from FDA.gov): Many medical devices now have the ability to connect to and communicate with other devices or systems.

Τι είναι Digital Health?

[Medical Device] +
[Internet of Things] +
[Big Data Analysis] +
[New data technologies] +
[Medical & Health Informatics]

Digital health includes categories such as mobile health (mHealth), health information technology (IT), wearable devices, telehealth, and personalized medicine (genomics, proteomics).

→ Better monitor our health & well-being
→ Improve health care and health outcomes
→ Make medicine more personalized

→ Empower patients! Patients and consumers can use digital health to better manage and track their health and wellness related activities.

Digital Health = **Medical Dev + IT + Informatics**

Point of Care Systems

Lateral Flow Tests w/ Digital capabilities

Systems Biology (Big Data) Genomics, Proteomics

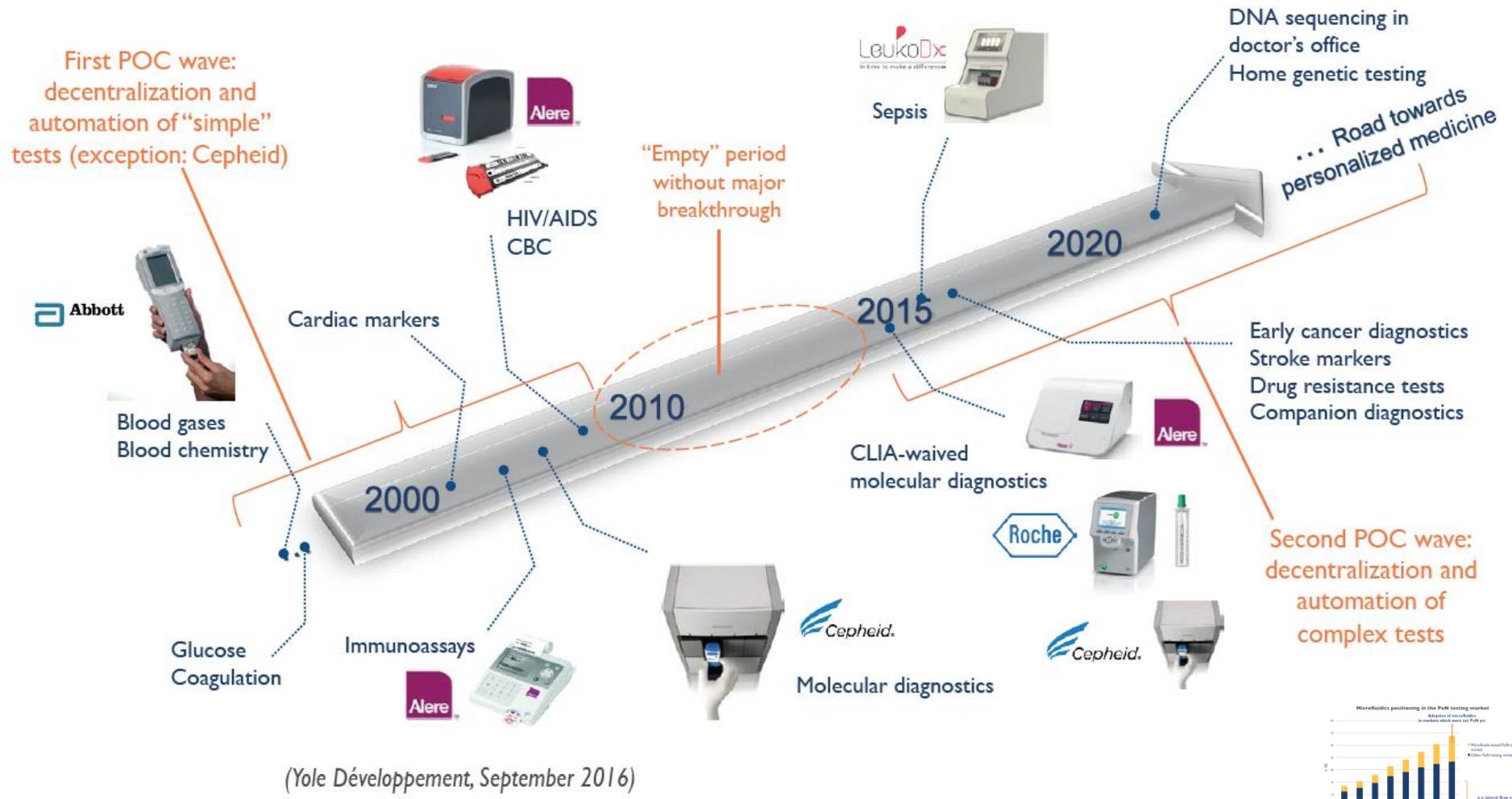
Wearables & Mobile Health

Σπιρομέτρηση (health, COPD, etc)

Καρδιακοί Παλμοί

Τρέμουλο Χεριών (monitoring & Parkinson)

Microfluidics for PoN testing: roadmap



(Yole Développement, September 2016)

Digital Health & Point of Care

Microfluidics for PoN testing: roadmap

Biopharma

Drug Manufacturing, Packaging & QC


Granulator


Tabletting Machine


Coating Machine


Video Inspection Machine


Container Washer


Containers

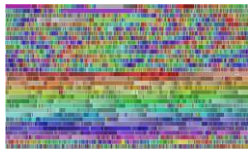

PTP Packaging Machine


Packaging Line


Automatic Warehouse

Research & Discovery

Genomics, Proteomics
New Instruments
& Data Measurements



Big Data Analysis
Systems Biology
Bioinformatics

Drug Discovery &
Personalized
Medicine

Clinical Development (phase I, II, III)

POC systems & Digital Health

Some Biomedical Engineering Companies abroad

Johnson & Johnson

DePuy

Boston Scientific

GE Healthcare

SIEMENS
medical

Medtronic

BAYER
Bayer HealthCare

BD

Boston Scientific
Defining tomorrow, today.

COVIDIEN

BARD

ETHICON

MEDRAD

Medtronic

ORTHOFIX

PHILIPS
sense and simplicity

smith&nephew

TERUMO

Abbott
Vascular

zimmer

(n=14)

Biomedical Engineering in Greece

Medical Devices

ΠΑΠΑΠΟΣΤΟΛΟΥ

micrel

Rontis
Driven by innovation™

Diagnostics

medicon

HBio

SMEs

Fasmatech
SCIENCE + TECHNOLOGY

BIONATURE

InSyBio
Intelligent Systems Biology

Tribe Wearables

Biovista
to seek - to know - to act

e-NIOS
e-Noesis Inspired Operational Systems

RTsafe

CLOUDPHARM

ladd//roller

ELdrug
DRUG RESEARCH AND DEVELOPMENT

PROT AT ONCE

+ many more SMEs

Φαρμακευτικές εταιρίες & Δερμοκαλυντικά (κατασκευαστές)

DEMO

Lavipharm

Boehringer Ingelheim

ELPEN

RAFARM
Health care. Human care.

Pharmathen
Innovation inspired by life

Galenica s.a.

KORRES

APIVITA

Automation, Manufacturing, Quality Assurance, Αναλυτικά όργανα, Οργάνωση παραγωγής, Παραγωγή, Διασκιοποίηση κτλ

Αντιπροσωπείες .... Logistics, support, & sales (τεχνικοί μηχανημάτων, implants, diagnostics κτλ)

Μαθήματα Βιοϊατρικής Μηχανικής ΜΜ ΕΜΠ

Αποκτάτε βασικές Γνώσεις Βιοιατρικής

Σχεδιαζετε Βιοιατρικές συσκευές (concept, market analysis, business plan, design)

Εφαρμογές σε Biomechanics (κατασκευαστές)

7ο Εξάμηνο	8ο Εξάμηνο	9ο Εξάμηνο
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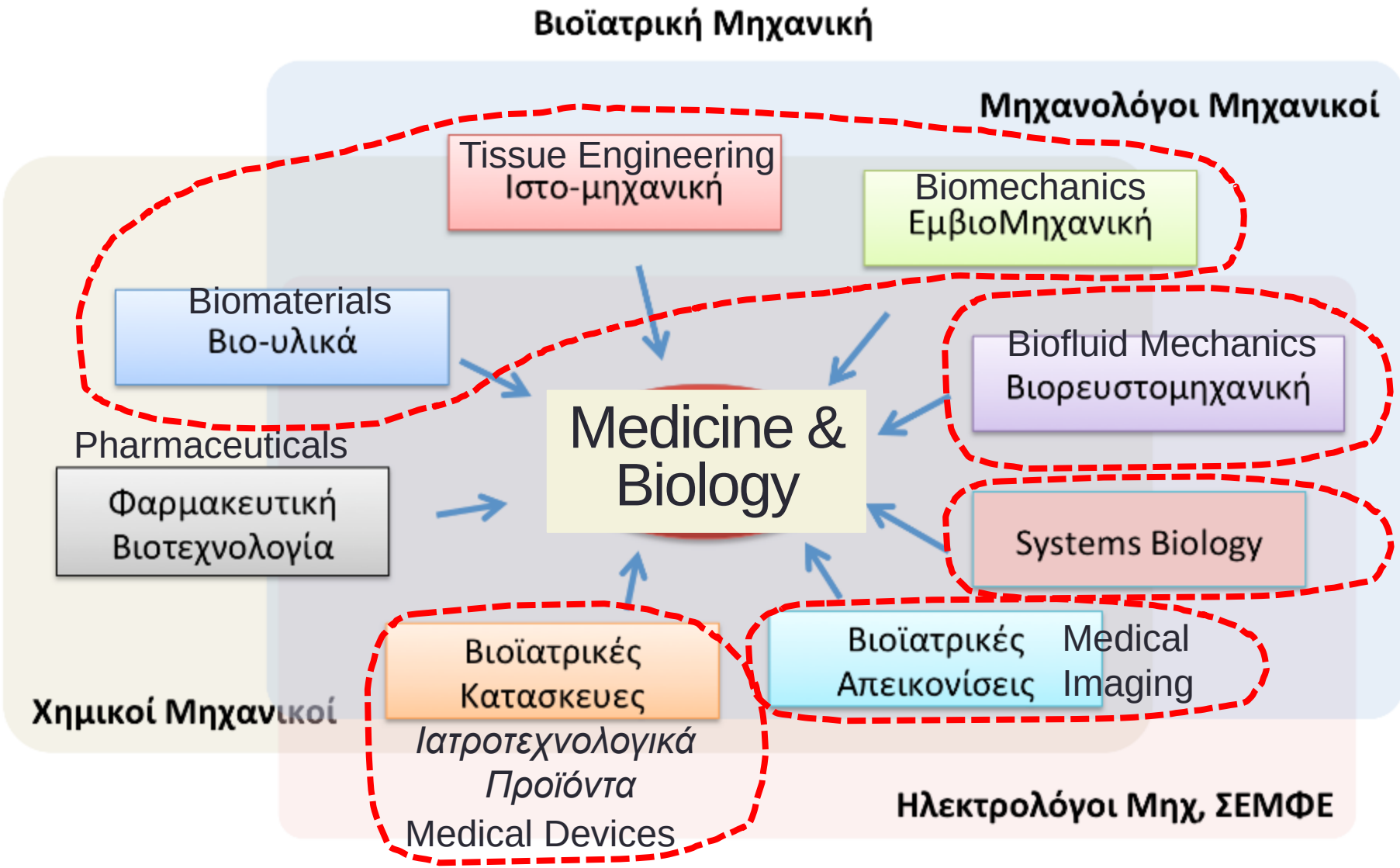
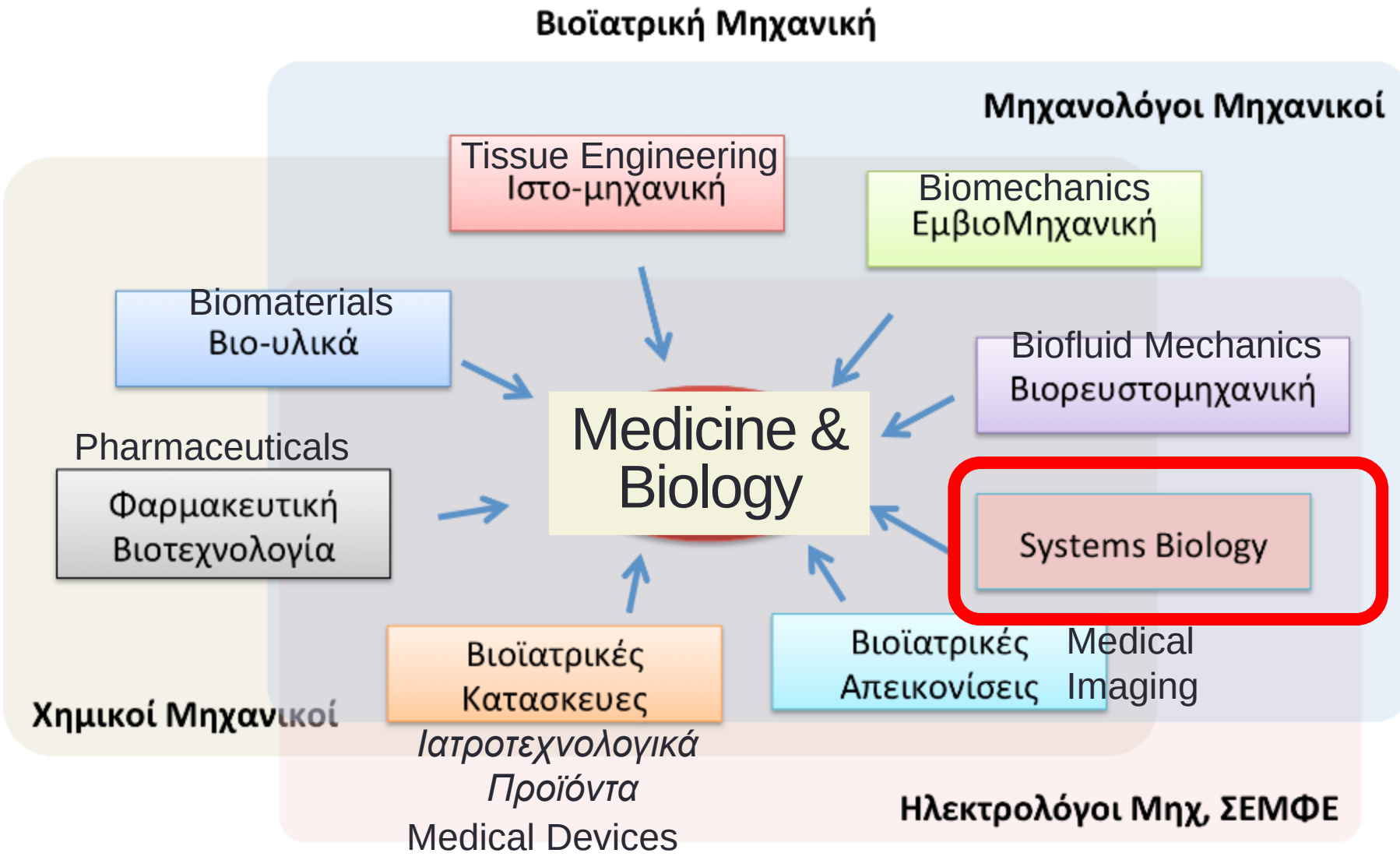
ΒΙΟΛΟΓΙΑ ΒΙΟΠΛΗΡΟΦΟΡΙΚΗ ΣΥΣΤΗΜΙΚΗ ΒΙΟΛΟΓΙΑ & ΓΕΝΙΚΕΣ ΕΦΑΡΜΟΓΕΣ - Βιοιατρικές Συσκευές - Ιστομηχανική & Βιουλικά	ΔΙΑΔΙΚΑΣΙΑ ΑΝΑΠΤΥΞΗΣ ΙΑΤΡΟΤΕΧΝΟΛΟΓΙΚΟΥ ΠΡΟΪΟΝΤΟΣ - Concept to Product - Regulation - Τεχνικές Μετρήσεων - PoC - Αρχές σχεδιασμού	- SOFT TISSUE MECHANICS - HARD TISSUE MECHANICS - ANATOMY - TISSUE ENGINEERING - BIOMATERIALS

Disciplines in Biomedical Engineering



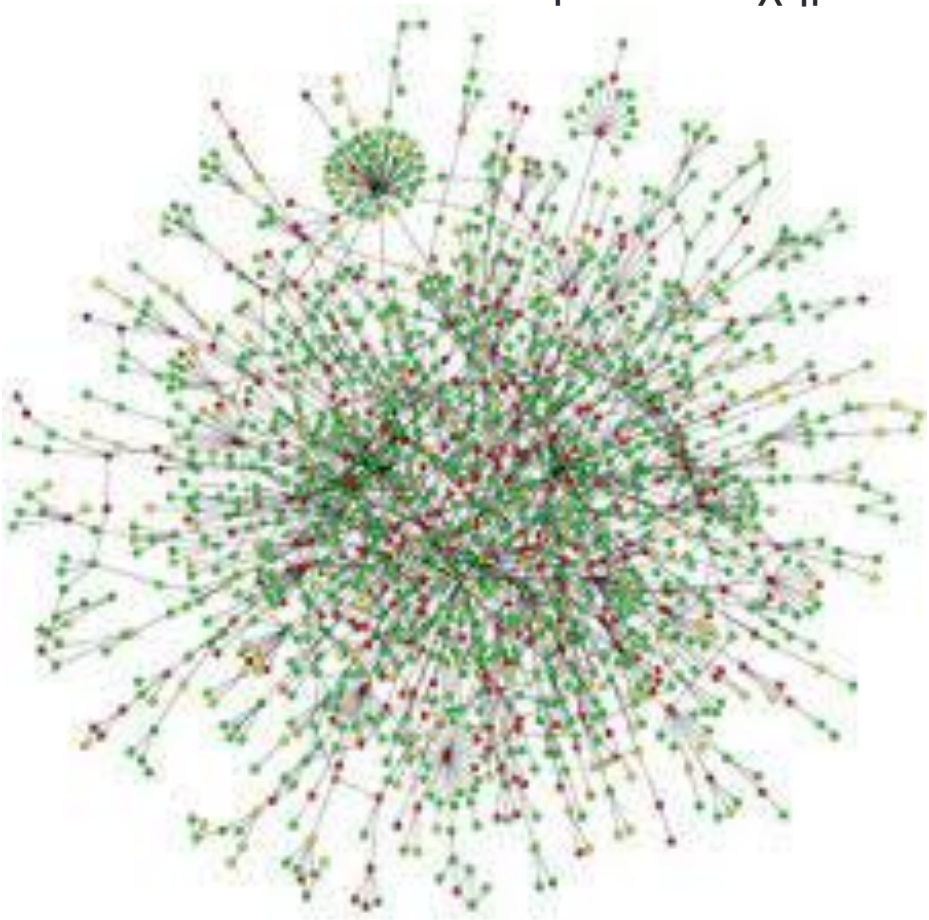
Disciplines in Biomedical Engineering

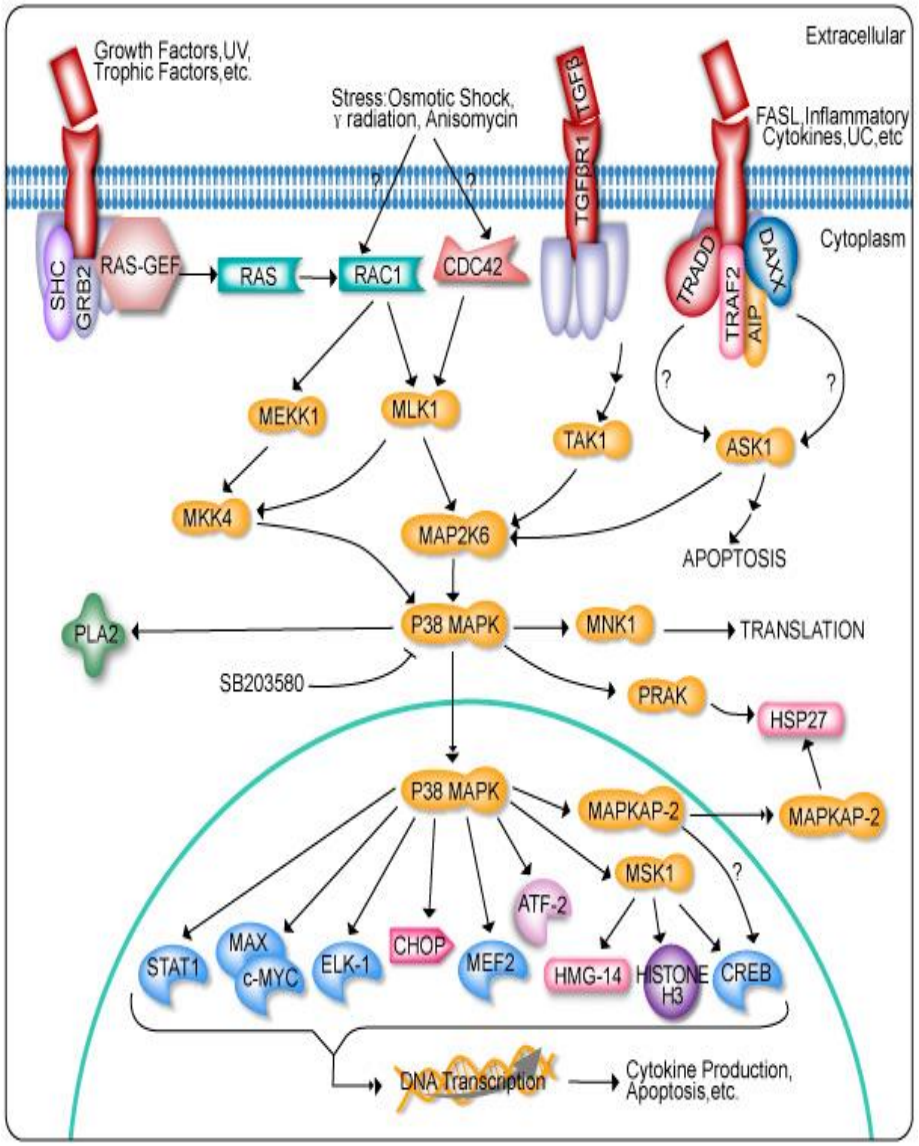


Systems Biology / Network Pharmacology

Η ερμηνεία βιολογικών καταστάσεων χρησιμοποιώντας θεωρία συστημάτων

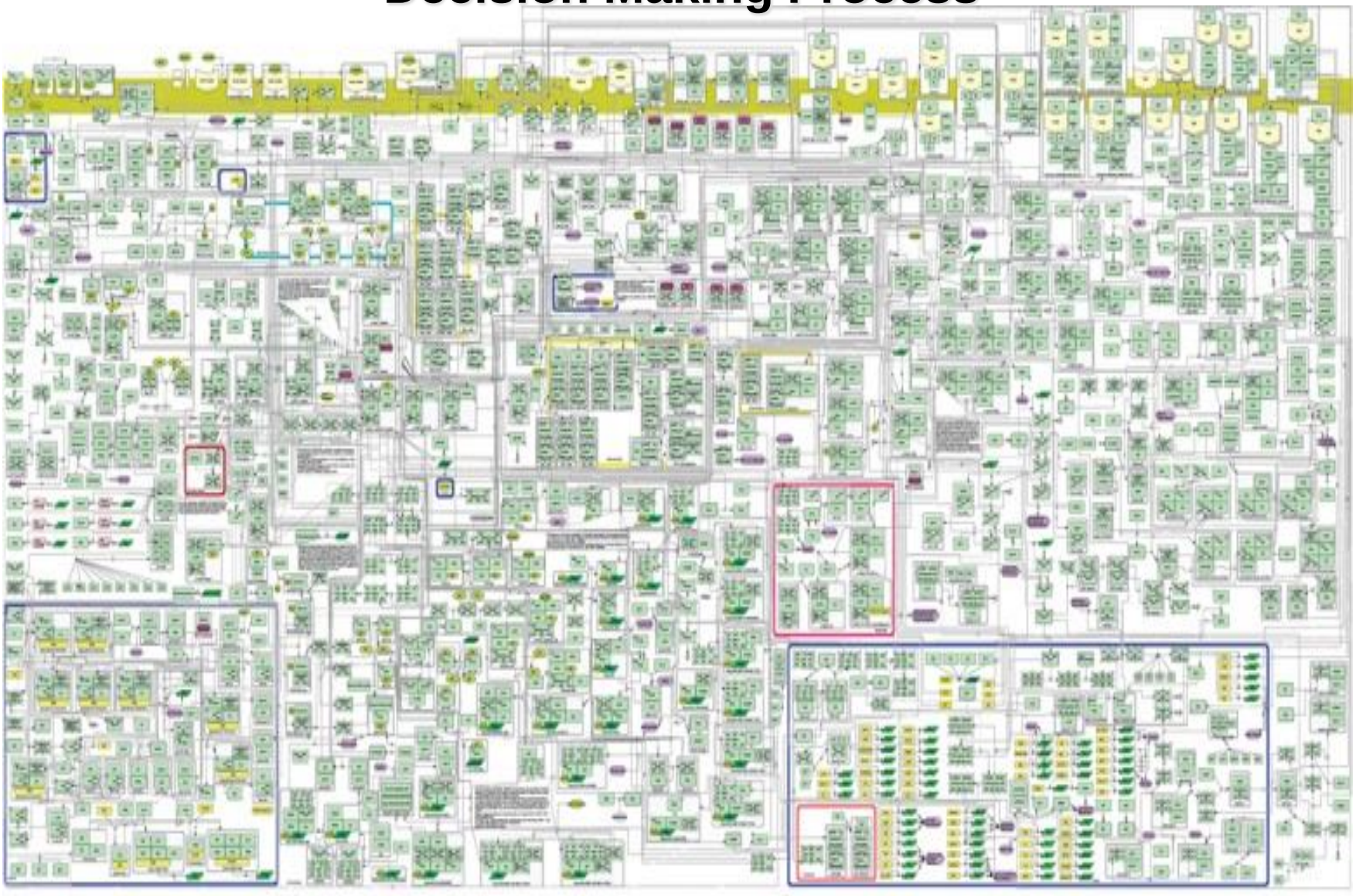
ΕΡΩΤΗΣΗ: Τι είναι το παρακάτω σχήμα?





Systems Biology / Network Pharmacology

Decision Making Process



Systems Biology in one slide: biology, data & models

BIOLOGY MODEL

In-vivo (organism)
In-vitro (cells)

SOLUTIONS

Monitor: Biomarkers
Test: New Biomodels
Intervene: Drugs, Biologics, Gene editing, Tissue Engineering

NEW TECHNOLOGIES & DATA THEY PRODUCE

Mass Spec	MET
Structure, *Sequence* Untargeted (MS) *Targeted (MRM-MS, Multiplex Elisa)*	PRO
RNA-seq Gene expr	RNA
Sequencing, SNPs, or *Chip-Seq* (Protein/DNA)	DNA

MODELLING

- ***Statistics***
- ***Machine Learning***
  Classification
  Clustering
  Regression
- **Data Reduction**
- **Network Models**
  Boolean, ODE, Fuzzy, Graph theory, Bayesian inference
- **Optimization**
  Dynamic Programing, Linear Programming

PHENOTYPES, MECHANISMS, & BEHAVIORS

In-vivo: Clinical Outcome, Disease Progression, Animal behavior (normal vs pathological)
In-vitro: Normal vs cancer cells, growth curve, live/dead assays, inflammation etc

Pipeline for data generation & analysis

Data collection
- Experimental Design
- Data Collection
- Public Data Repositories

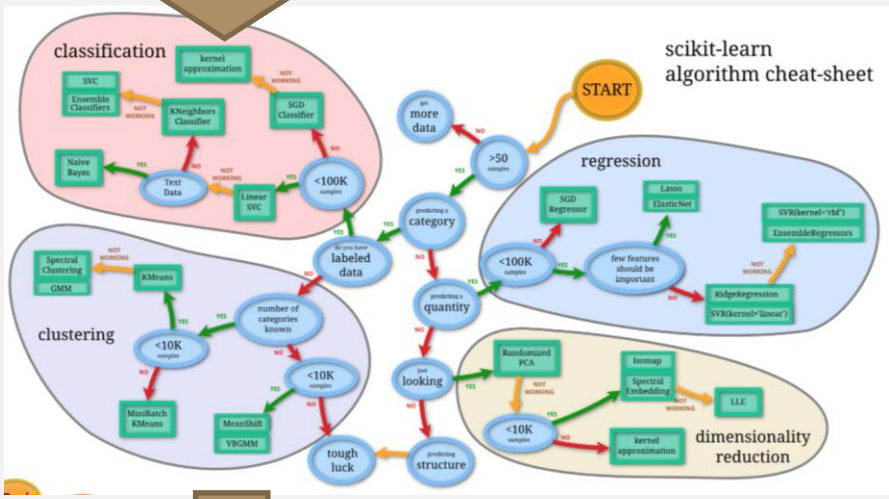
Data Normalization
- Intra-Normalization
- Inter-Normalization

Data Visualization
- BoxPlots, Volcano, HeatMaps, Subplots

Method(s) Selection for Modelling
- *Classification*
- *Clustering*
- *Dimensionality Reduction*
- *Regression*

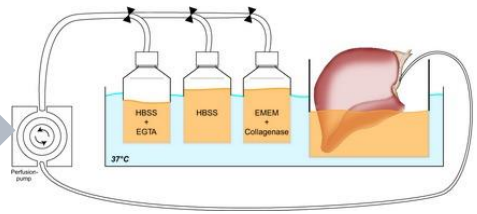
- Network Analysis

- Optimization

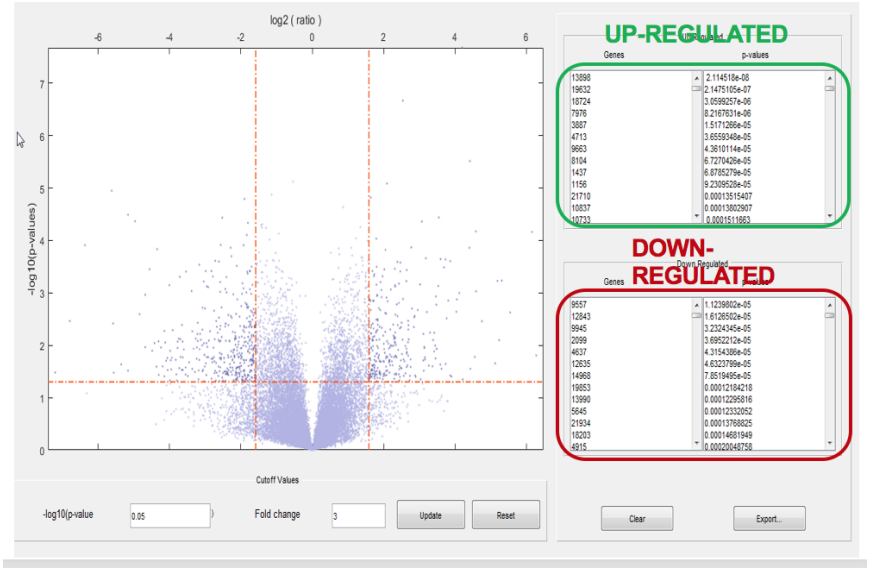


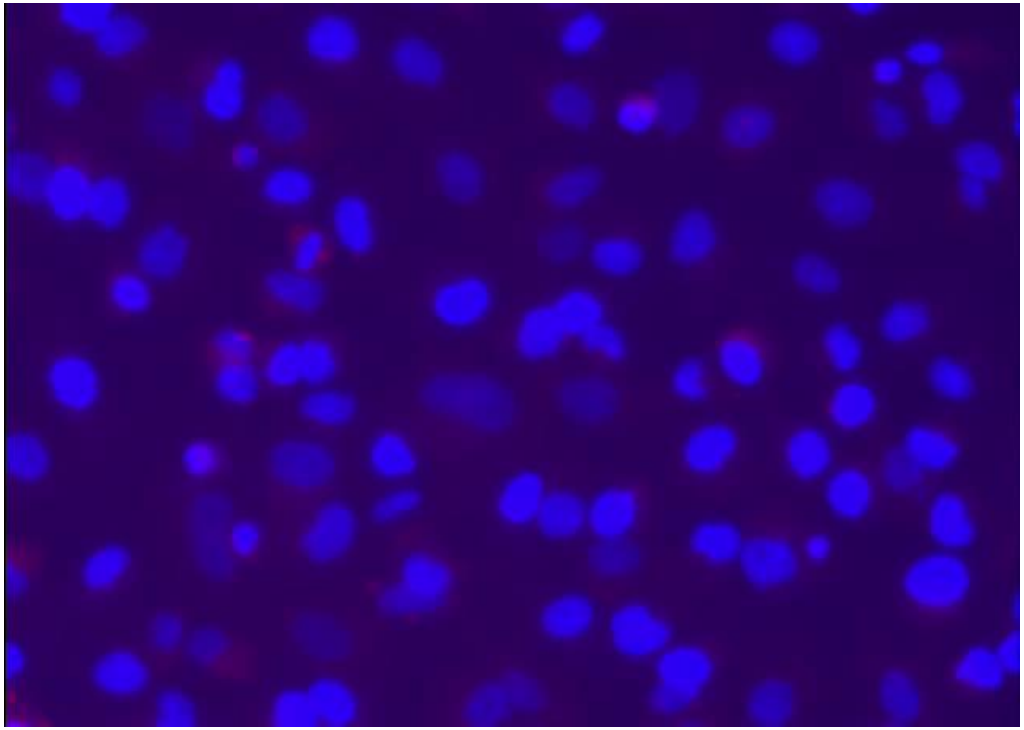
Biological Impact
- Biomarker Selection
- Patient Classification
- Target Selection
- Mechanism Identification

Applications: Drug repurposing for NAFLD



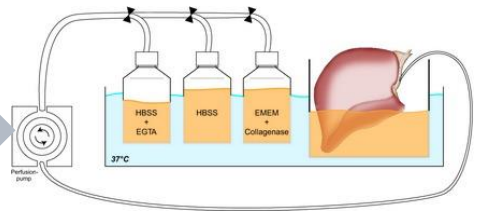
NAFLD (lipid accumulation)





GEO → GENES → NETWORKS → DRUGS THAT HIT THE SAME AREA (INVERSE OR CAUSE?)

Applications: Drug repurposing for NAFLD



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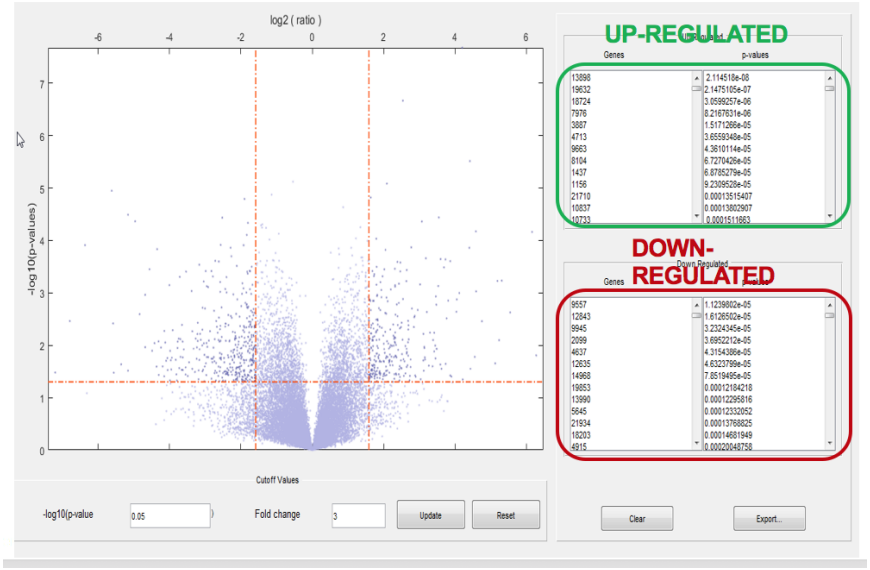
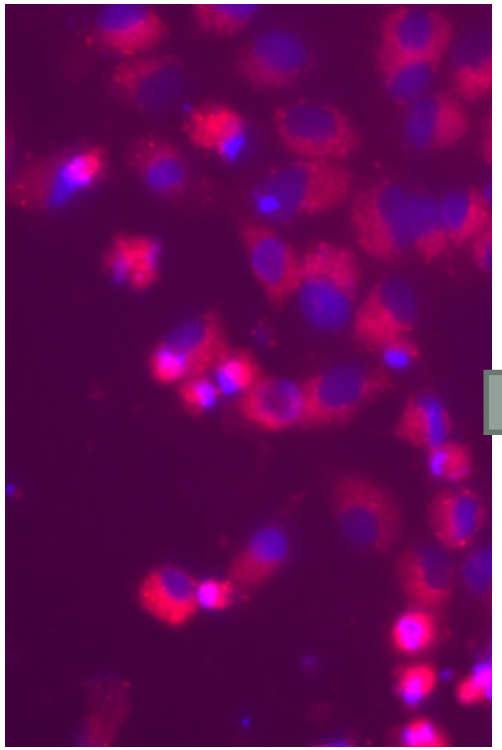
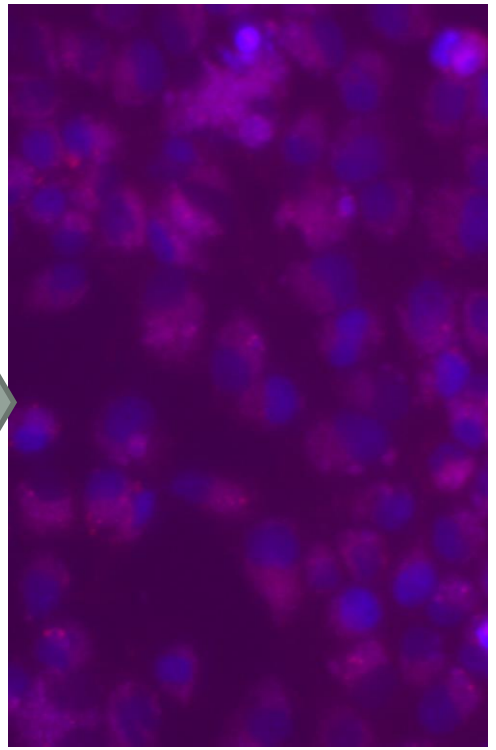
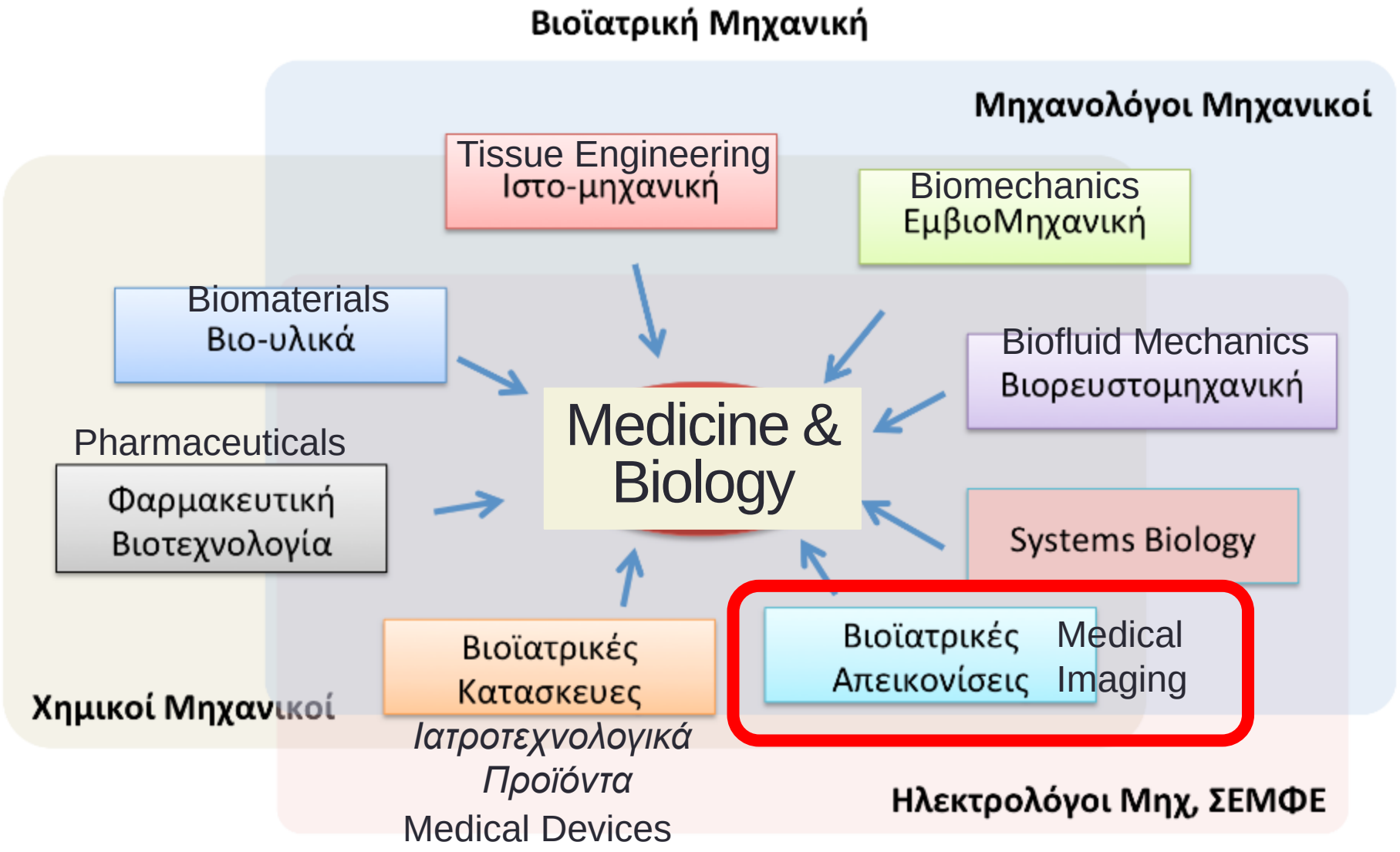


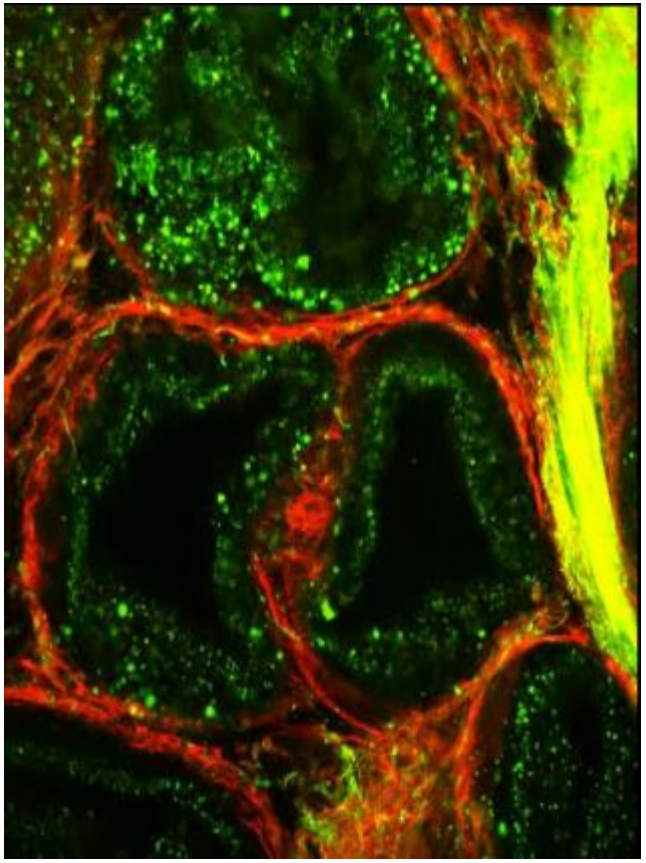




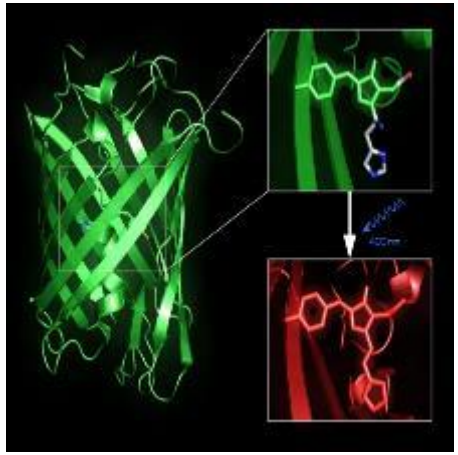
Disciplines in Biomedical Engineering



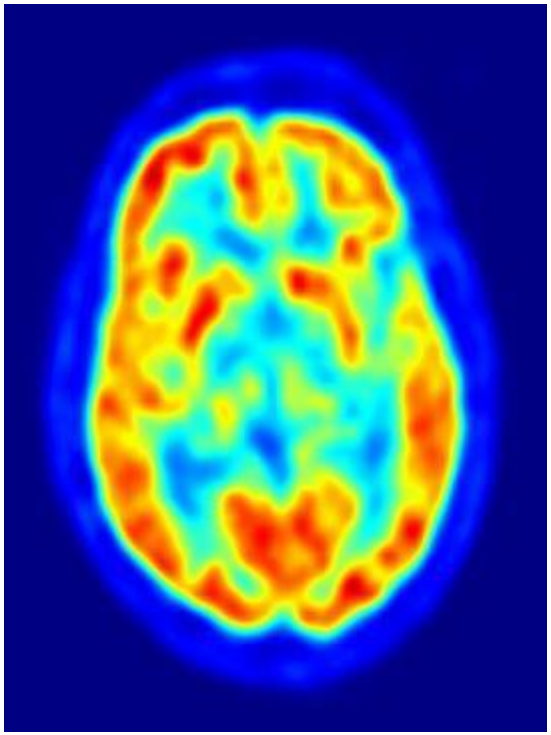
Medical Imaging



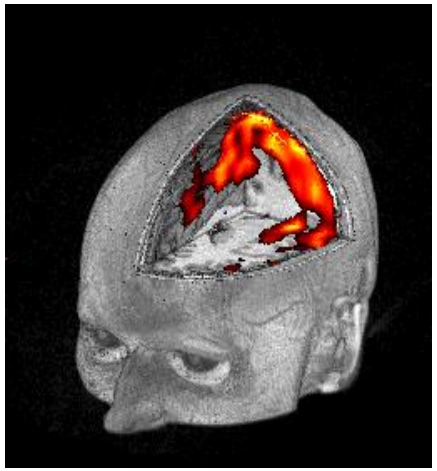
Fluorescent imaging (Cornell.edu)



GFP structure (semrock.com)

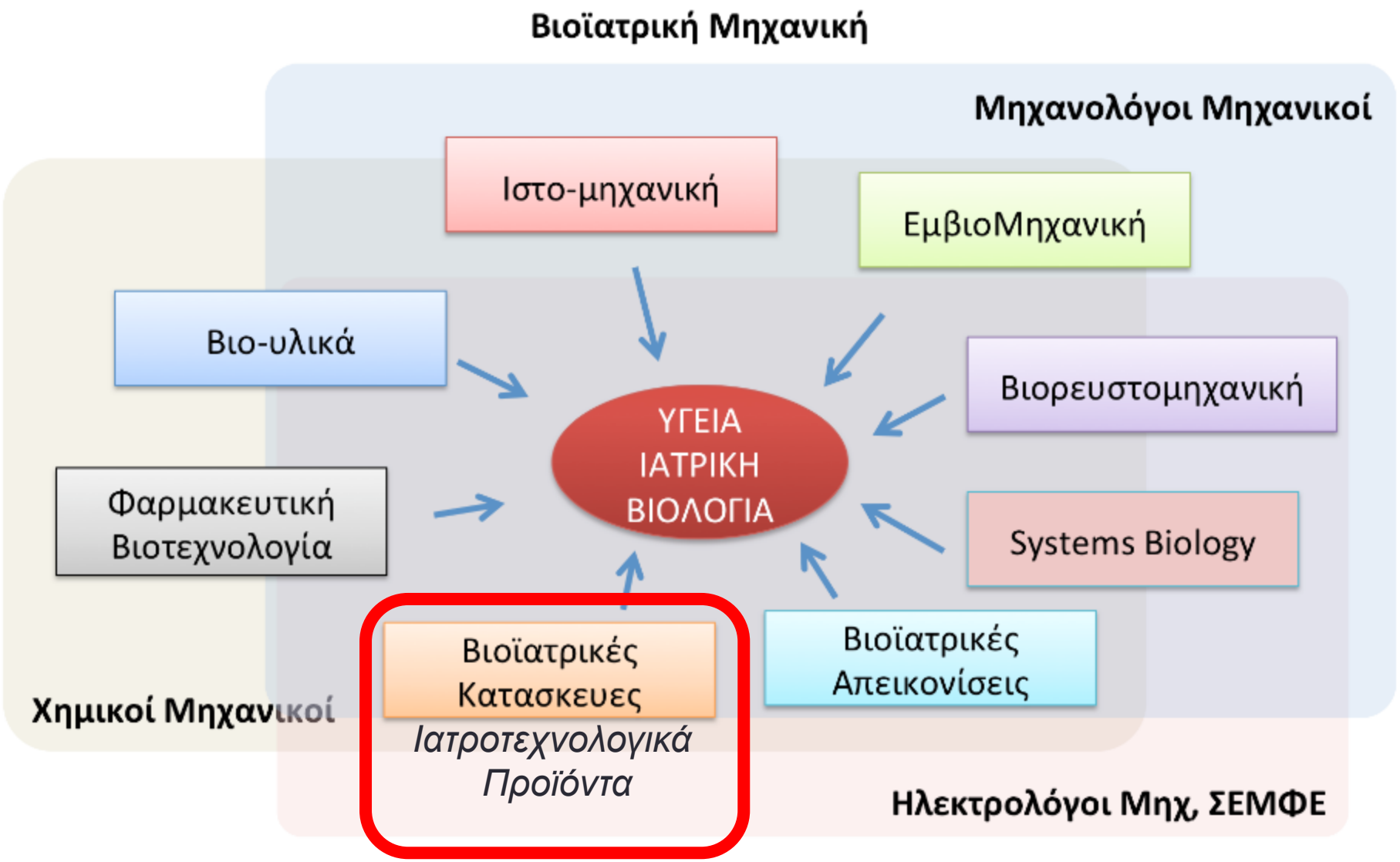


PET imaging



fMRI imaging

Κατηγορίες Βιοιατρικής Μηχανικής



Medical Device

Ιατροτεχνολογικά Προϊόντα

Βιοϊατρικά Προϊόντα

> 5000 types of medical devices (FDA list)!

Medical device (brief):

An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose. Typically, the purpose of a medical device is not achieved by pharmacological, immunological or metabolic means.

Medical equipment:

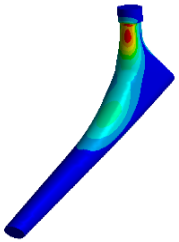
Medical devices requiring calibration, maintenance, repair, user training and decommissioning – activities usually managed by engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following disease or injury

Medical Device (concept→business plan→design→manufacture*)

Διαγνωστικά μηχανήματα

Νοσοκομειακά μηχανήματα

Μηχανικά Εμφυτευματα



Ιστομηχανική (πχ Βαλβίδες καρδίας)

Τεχνητά Μέλη Rahabilitation

PoC

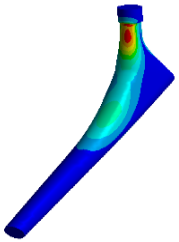
Imaging

Medical Device (regulated)

Διαγνωστικά μηχανήματα

Νοσοκομειακά μηχανήματα

Μηχανικά Εμφυτευματα



Ιστομηχανική (πχ Βαλβίδες καρδίας)

Τεχνητά Μέλη Rahabilitation

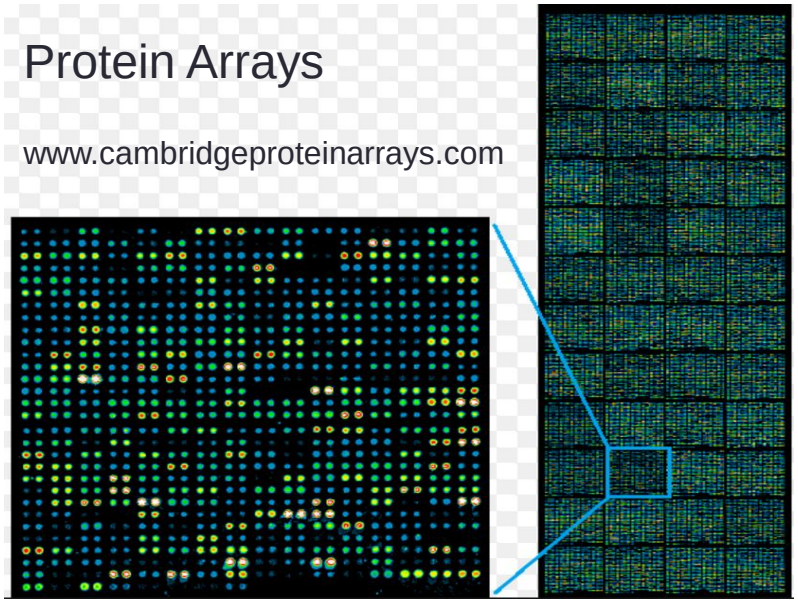
PoC

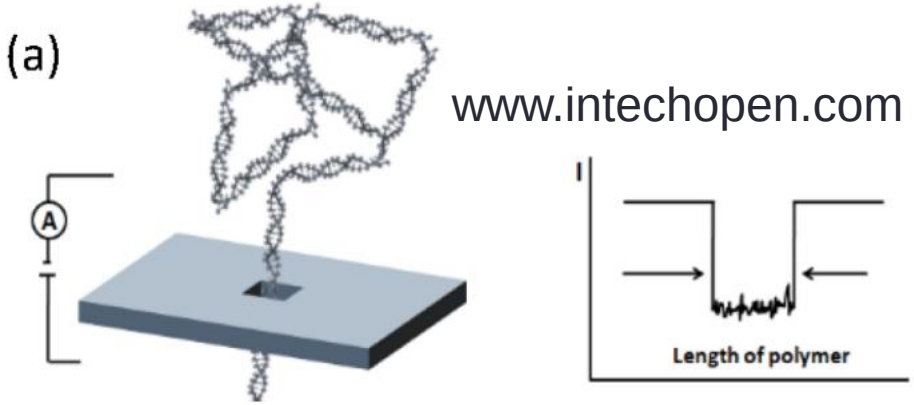
Imaging

Bioinstrumentation (non-regulated) / life science

Protein Arrays

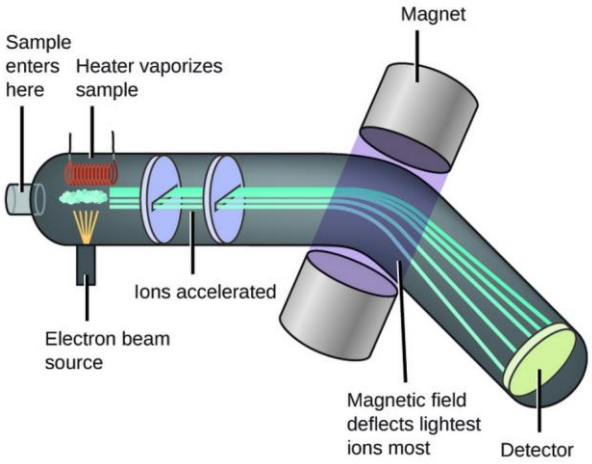
www.cambridgeproteinarrays.com





www.intechopen.com

Nanopores (DNA measurements)



www.khanacademy.org

Mass Spec
Vs
Mass Spec ISO13485

8th Semester: MEDICAL DEVICE

IDENTIFY

STAGE 1 NEEDS FINDING
- 1.1 Strategic Focus
- 1.2 Observation and Problem Identification
- 1.3 Need Statement Development

STAGE 2 NEEDS SCREENING
- 2.1 Disease State Fundamentals
- 2.2 Treatment Options
- 2.3 Stakeholder Analysis
- 2.4 Market Analysis
- 2.5 Needs Filltering

INVENT

STAGE 3 CONCEPT GENERATION
- 3.1 Ideation and Brainstorming
- 3.2 Concept Screening

STAGE 4 CONCEPT SELECTION
- 4.1 Intellectual Property Basics
- 4.2 Regulatory Basics
- 4.3 Reimbursement Basics
- 4.4 Business Models
- 4.5 Prototyping
- 4.6 Final Concept Selection

IMPLEMENT

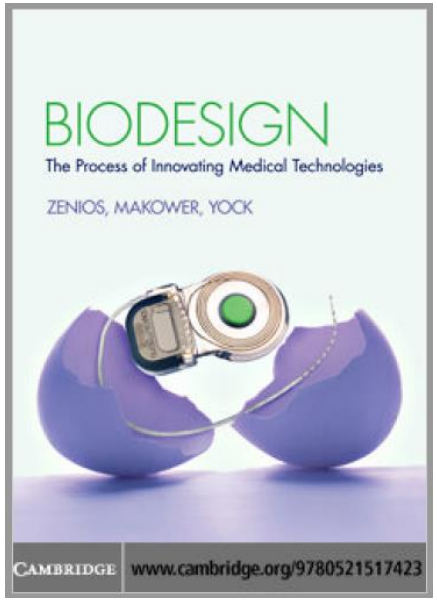
STAGE 5 DEVELOPMENT STRATEGY AND PLANNING
- 5.1 Intellectual Property Strategy
- 5.2 Research and Development Strategy
- 5.3 Clinical Strategy
- 5.4 Regulatory Strategy
- 5.5 Quality and Process Management
- 5.6 Reimbursement Strategy
- 5.7 Marketing and Stakeholder Strategy
- 5.8 Sales and Distribution Strategy
- 5.9 Competitive Advantage and Business Strategy

STAGE 6 INTEGRATION
- 6.1 Operating Plan and Financial Model
- 6.2 Business Plan Development
- 6.3 Funding Sources
- 6.4 Licensing and Alternate Pathways

Επιχειρισιακός & άλλοι τομείς

Κατασκευαστικός Τομέας

Source: Biodesign



Medical Devices

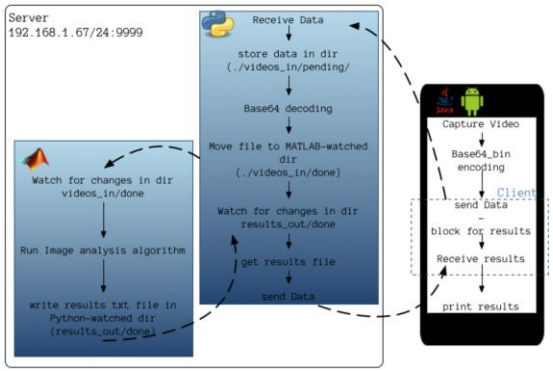
Smartphone microscopy

Live cell monitoring in the incubator
Smartphone enabled

Maxairas et al. 2015

PoC for Semen Analysis

→ In-home semen analysis
→ Smartphone integration for personalized treatment



Koukis et al. 2016

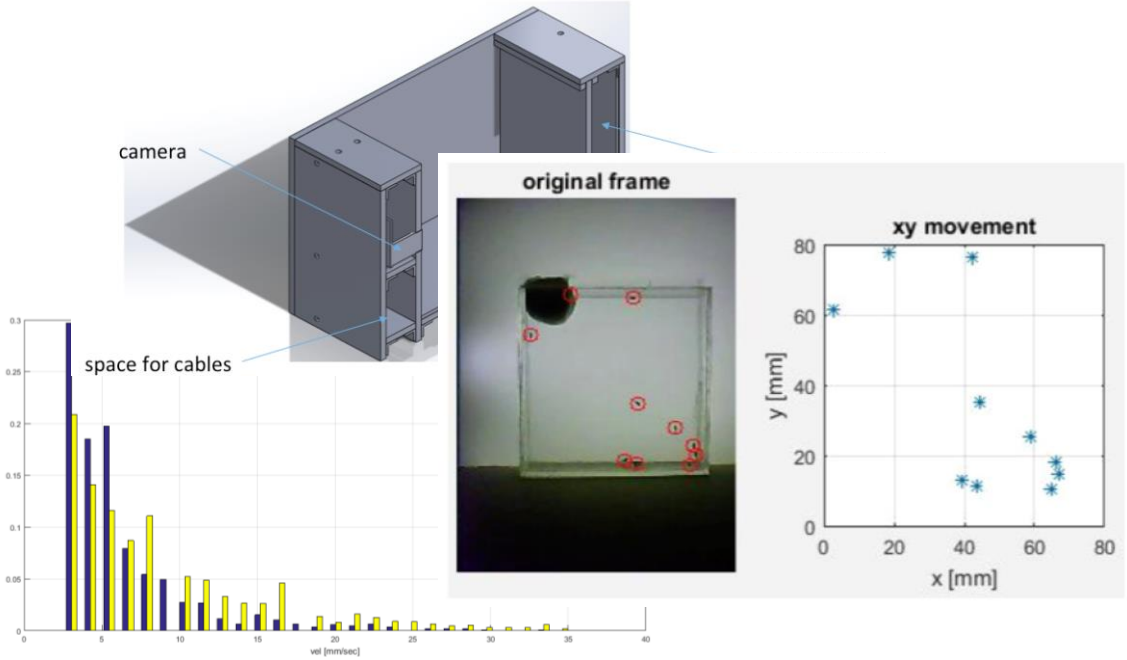
Medical Devices

Multiplex Proteomic System

Drosophila Tracker

w/ Dr Trougakos Lab @ UoA

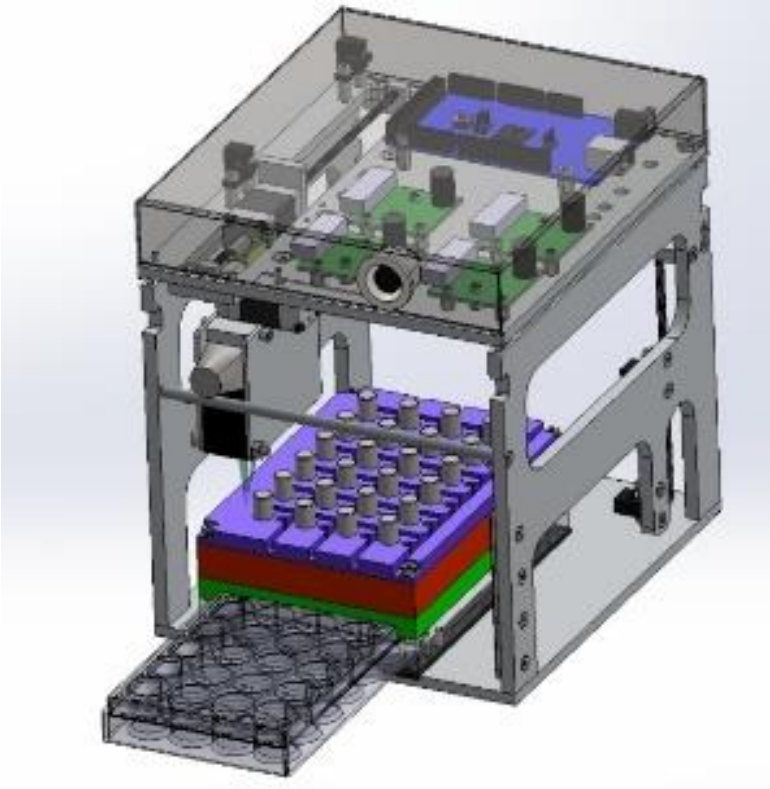
- → ~75% homology to human DNA
- → 24/7 monitoring
- → In-vivo platform for drug discovery



Kanakaris et al. 2015

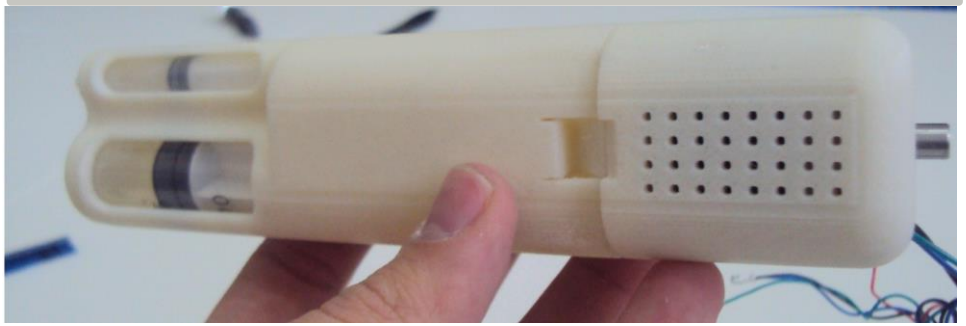
Medical Devices

Mechanical Testing of Cartilage Samples

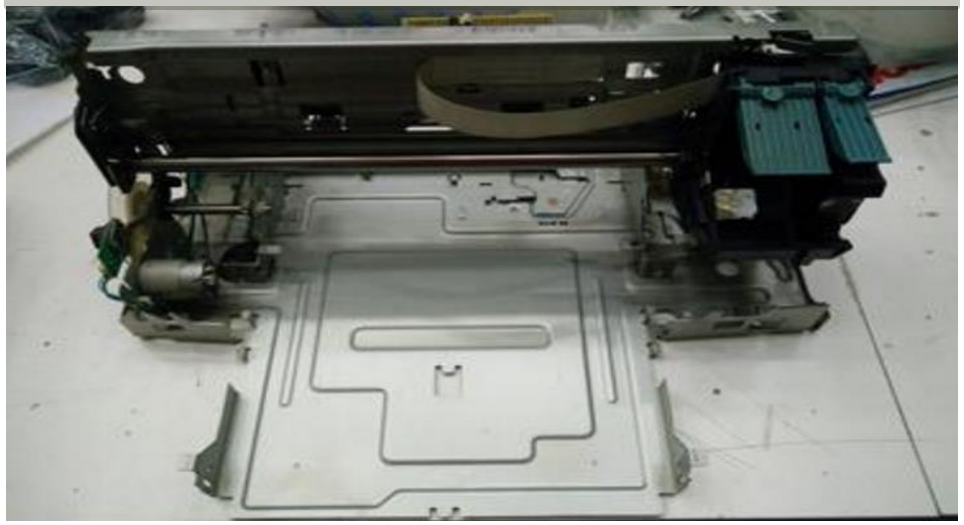


Tzeranis et al. 2017

Handheld BioPen for T.Eng.



Ab-Printing *(for lateral flow tests)*



8th Semester: MEDICAL DEVICE

Medical Devices

DESIGN FOR MEDICAL DEVICE vs OTHER

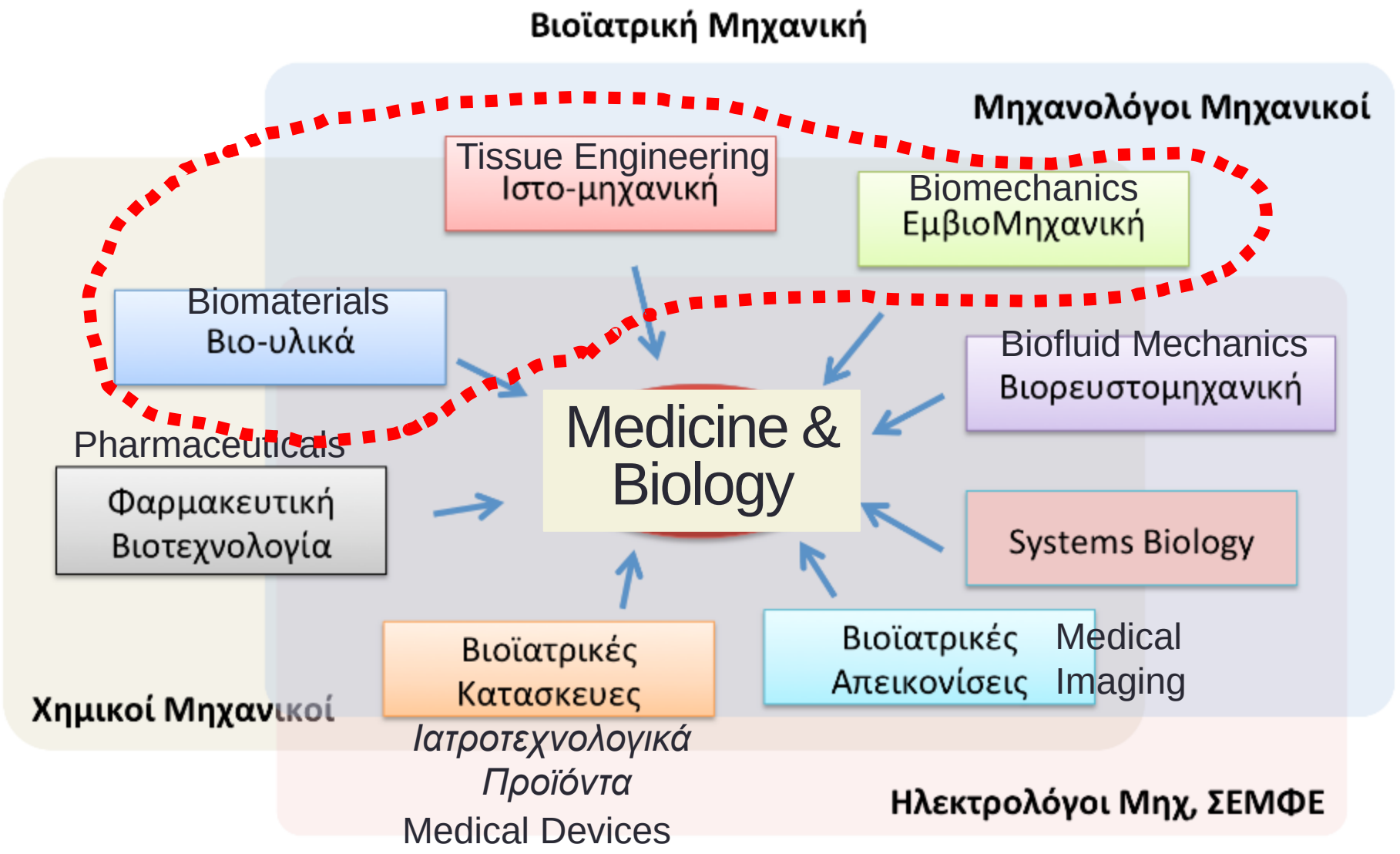
A REGULATED MARKET
(MED DEVICE)

- **Difficult to identify need**
- “Easy” to design
- “Easy” to penetrate marker

CONSUMER MARKET

- **Easy to find needs**
- Fierce competition
- Hard to find a good design
- Hard to penetrate the market

Disciplines in Biomedical Engineering: **BIOMECHANICS**



Biomechanics & Tissue Engineering

ANATOMY 101

Understand Anatomy and Physiology
(clinician point of view)

Tissue & Joint Mechanics

Understand their function(engineer)

Soft Tissue Mechanics
Hard Tissue Mechanics
Cell mechanics
Kinematics
Biomaterials

Application

Problems and Solutions

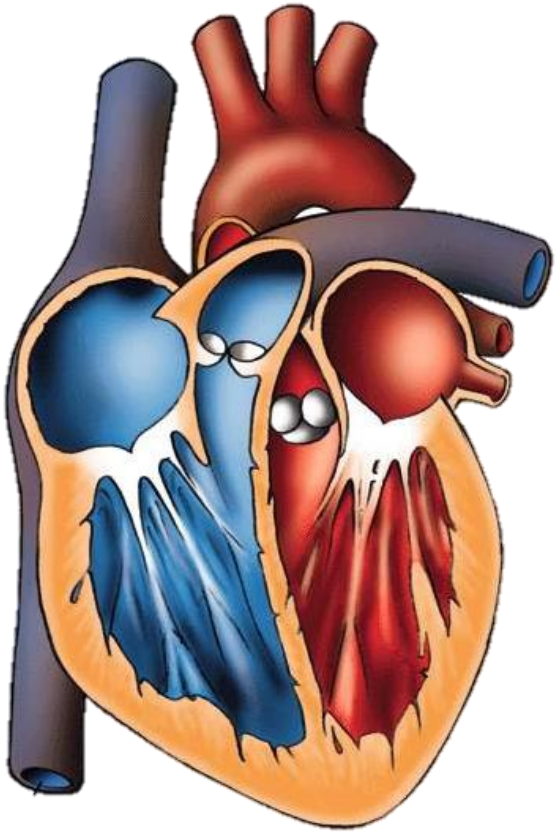
- **Tissue engineering**
- **Orthopaedics**
- **Pulmonary**
- **Cardiovascular**
- **Renal**

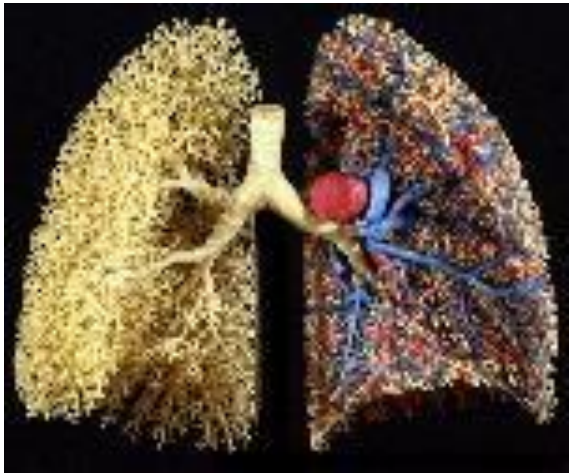
Syllabus

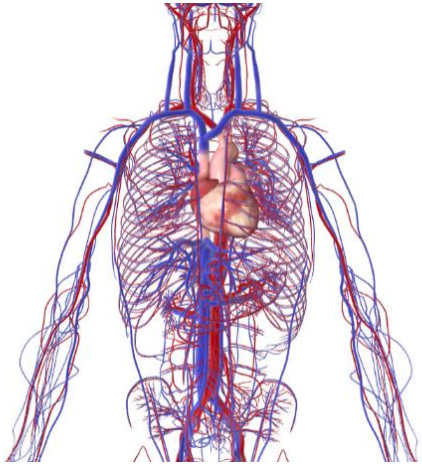
Class	Description	
1ο	Introduction	
2ο	Anatomy 101	
3ο	Tissue and Joint Mechanics	
4ο	Numerical and Experimental Methods in Biomechanics	
5ο	Practical course : Implant fitting study I	
6ο	Practical course : Implant fitting study II	
7ο	Tissue Engineering	
8ο	Cell Mechanics	
9ο	Practical course: FEM Hip Implant Study	
10ο	Practical course: FEM Hip Implant Study	

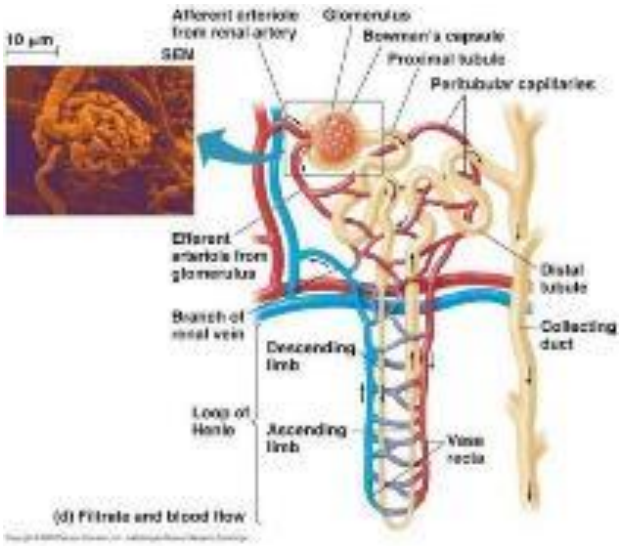
Anatomy 101

Understand the anatomy and function of heart, lungs and kidneys







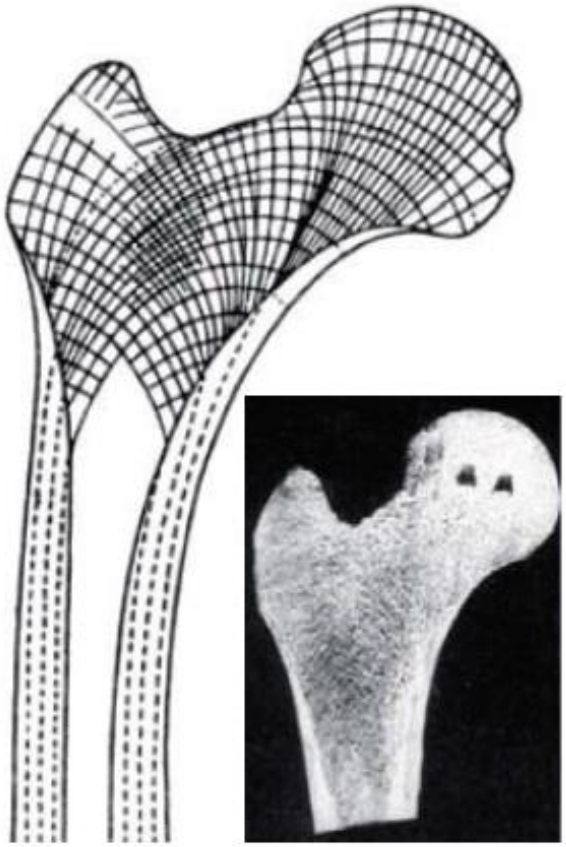


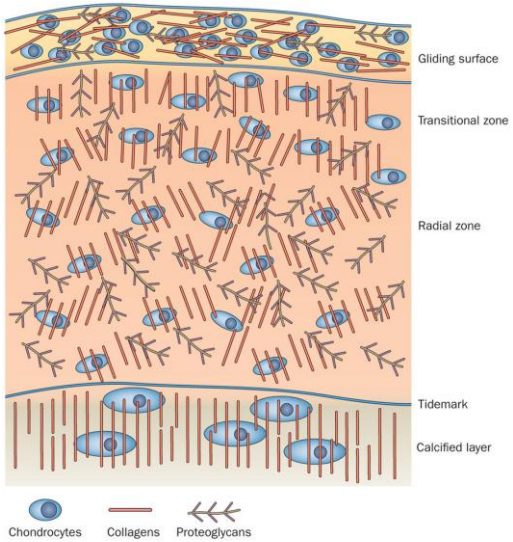
Anatomy 101

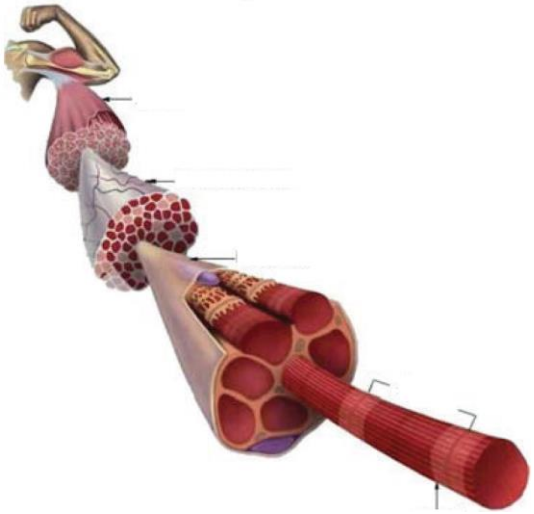
Pathologies and some current devices for cardiovascular, pulmonary and renal application

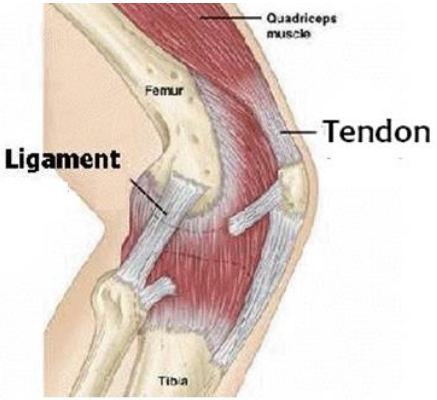
Tissue and joint mechanics

Understand function and mechanical properties of tissues involved in human locomotion



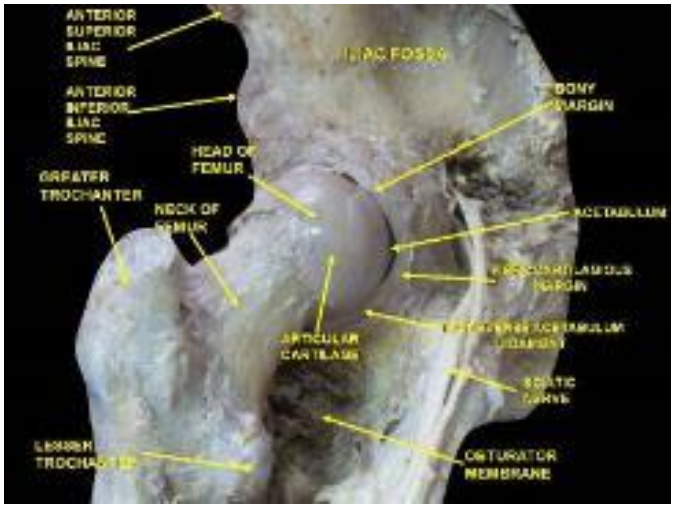


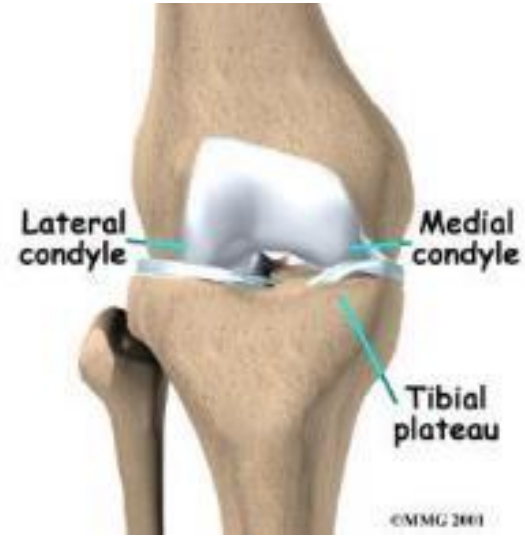


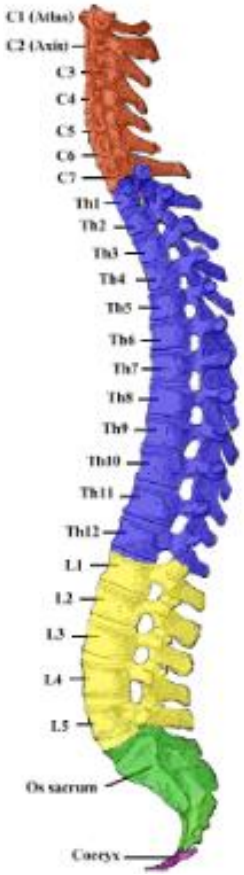


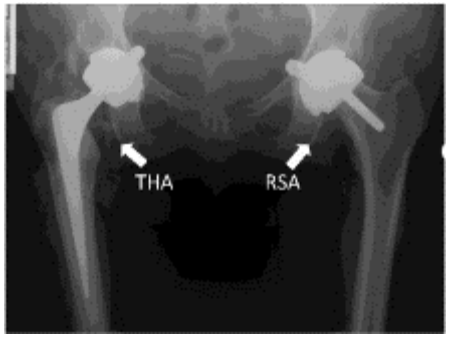
Tissue and joint mechanics

Understand anatomy and function of the main joints (knee, hip, spine). Pathologies and therapies (devices)







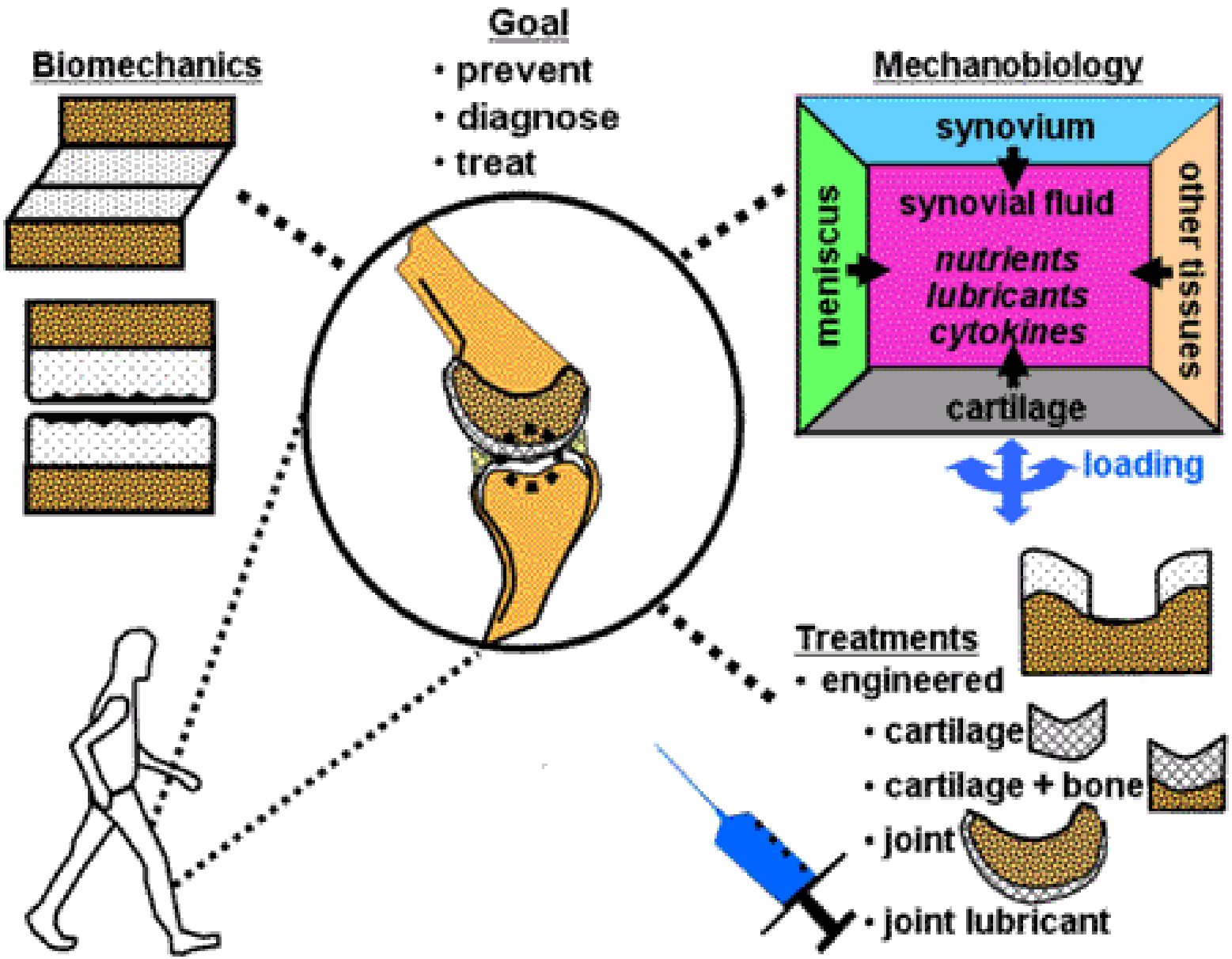



Quelle: www.zimmergermany.de

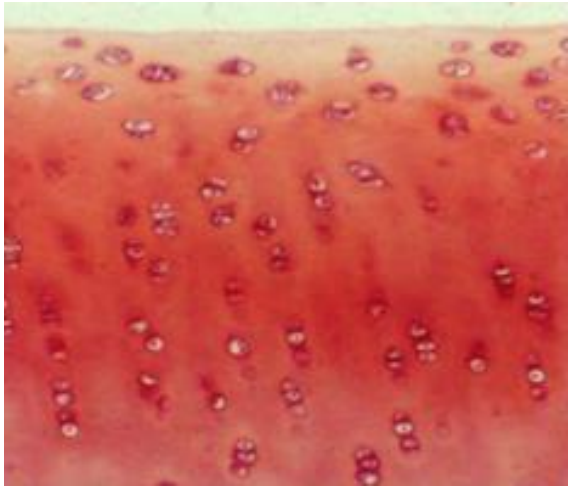

Quelle: www.zimmergermany.de


Quelle: www.zimmergermany.de

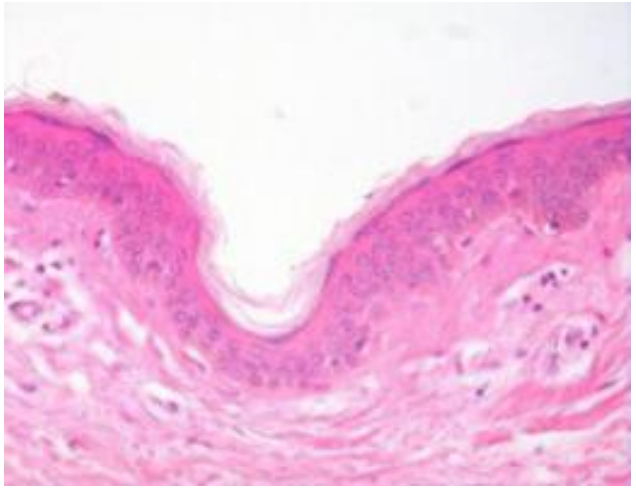
Tissue and joint mechanics: Cartilage



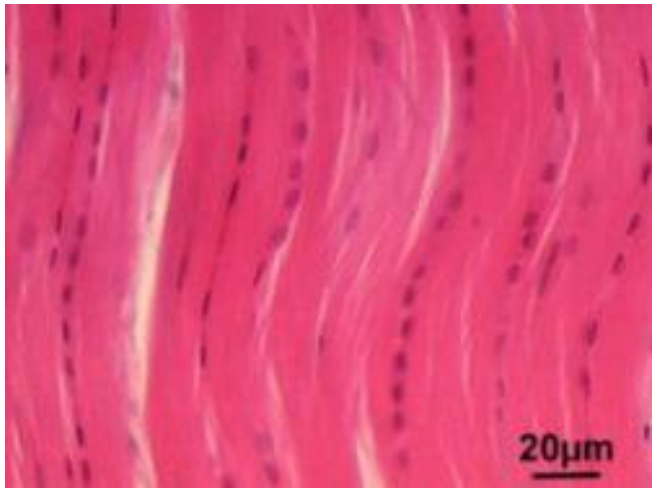
Soft Tissue Mechanics



Cartilage



Skin

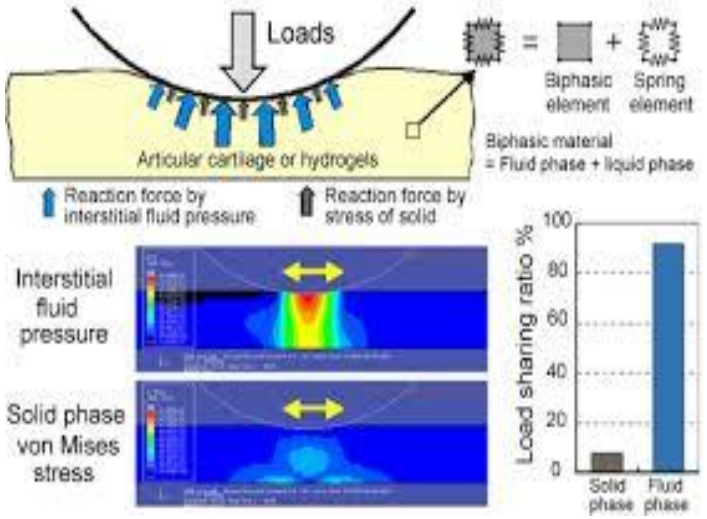


Tendon / Ligament

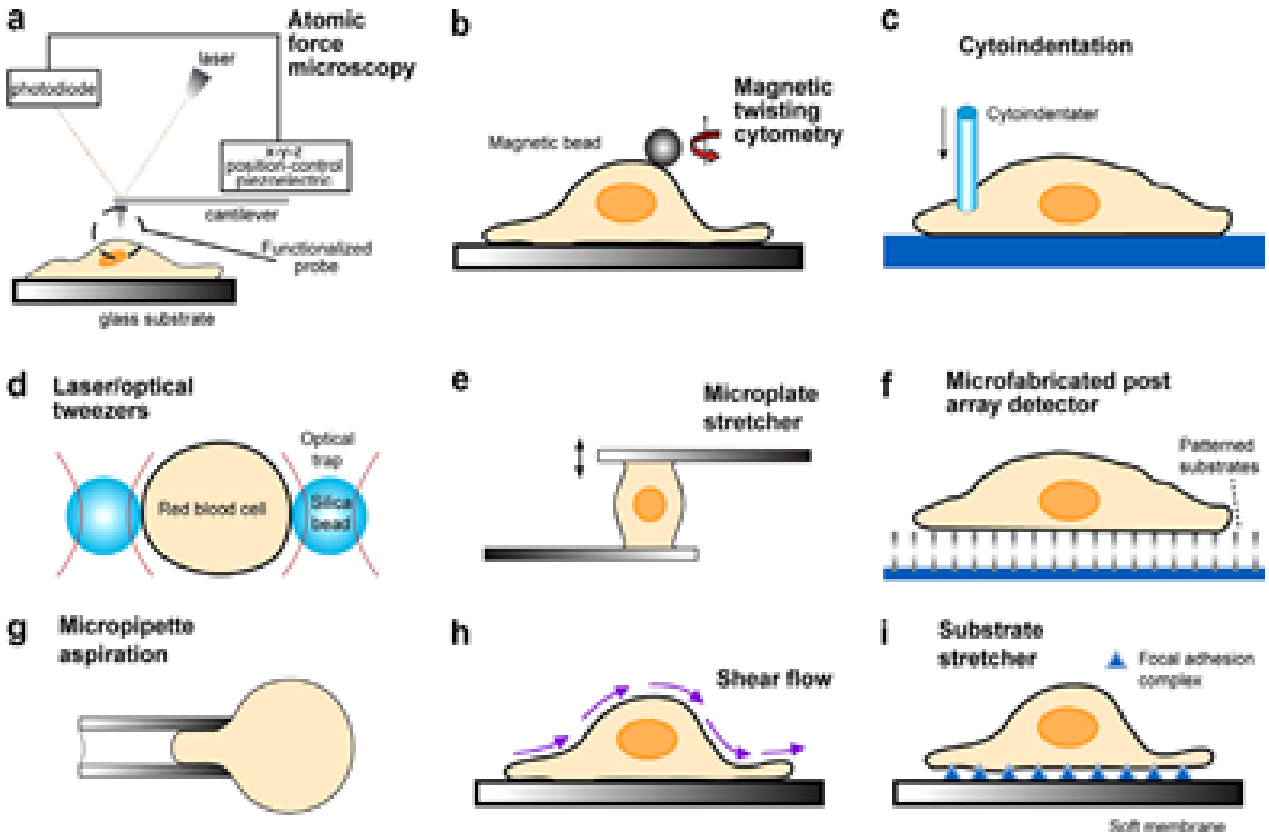
→ Solid Mechanics

→ Biphasic material

→ Triphasic material

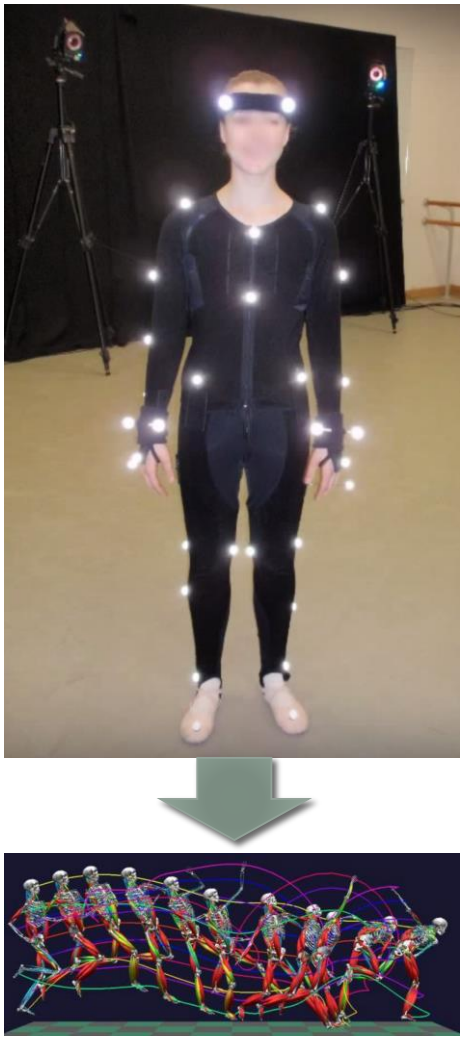


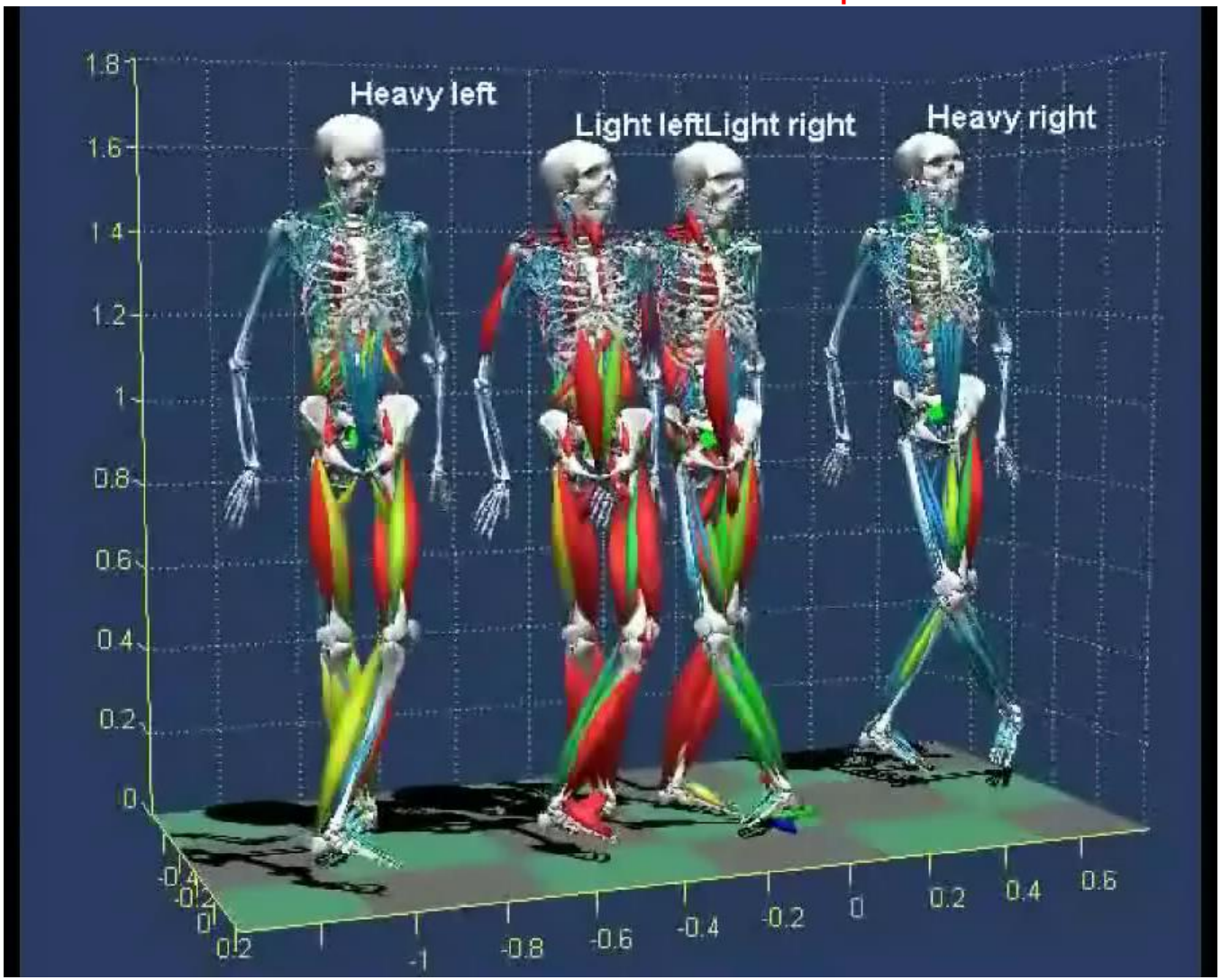
Cell Mechanics



Sports Biomechanics & Gait Analysis

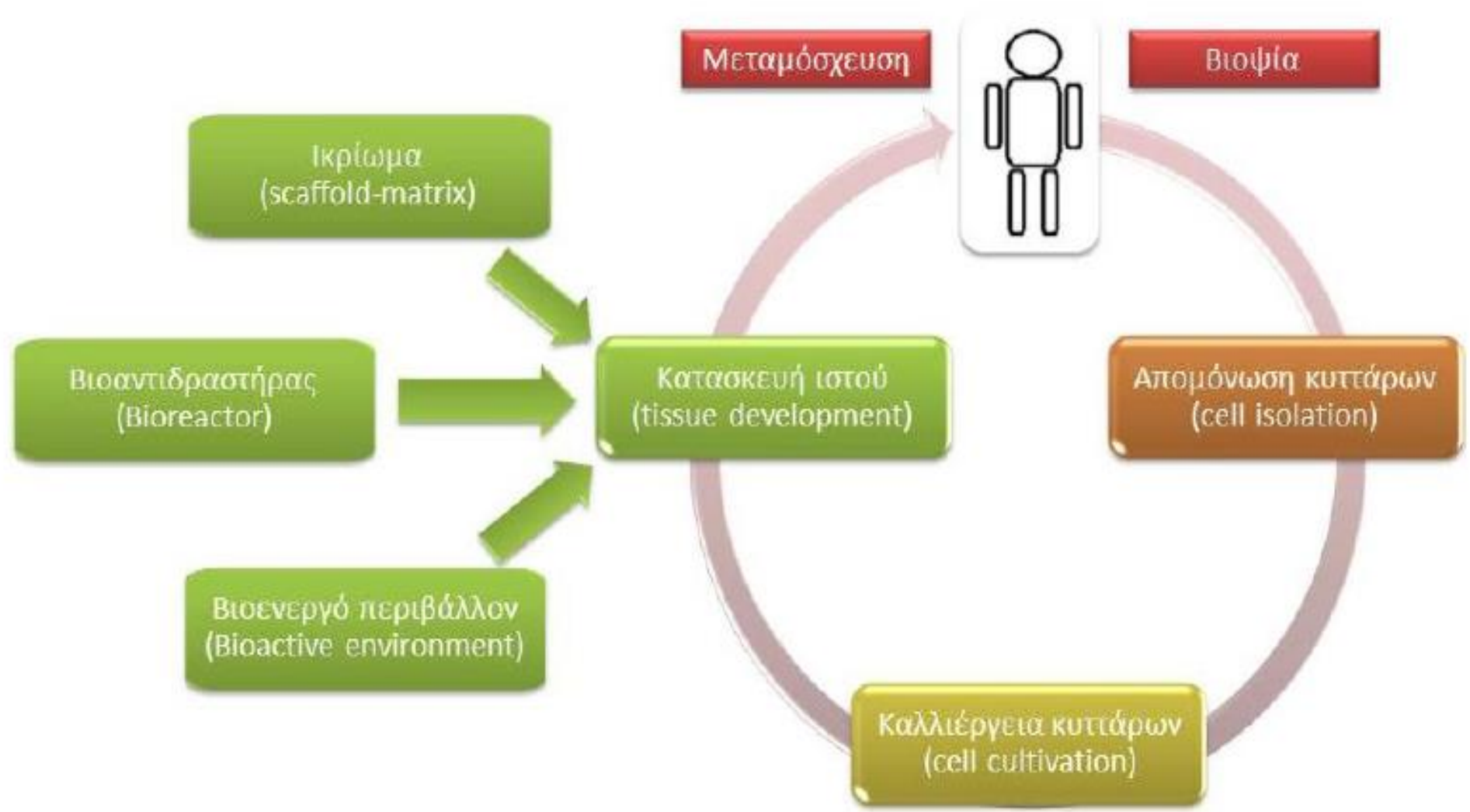
MOV01-Sports-Biomechanics





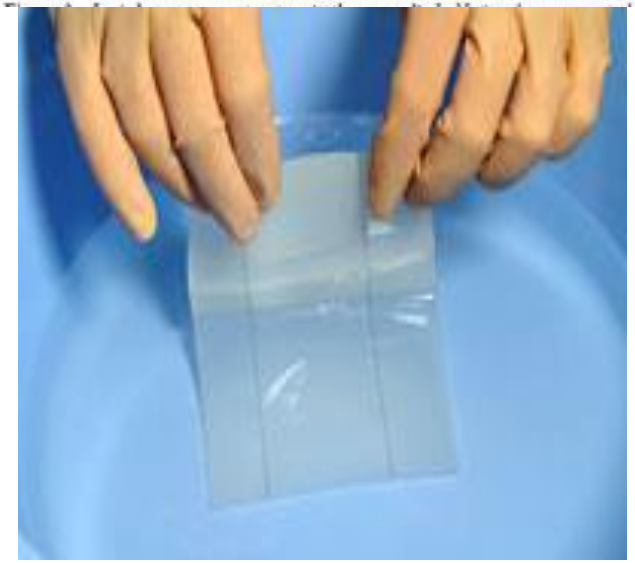
Reference: Biomechanics of Bodies (BoB) from: www.marlbrook.com/

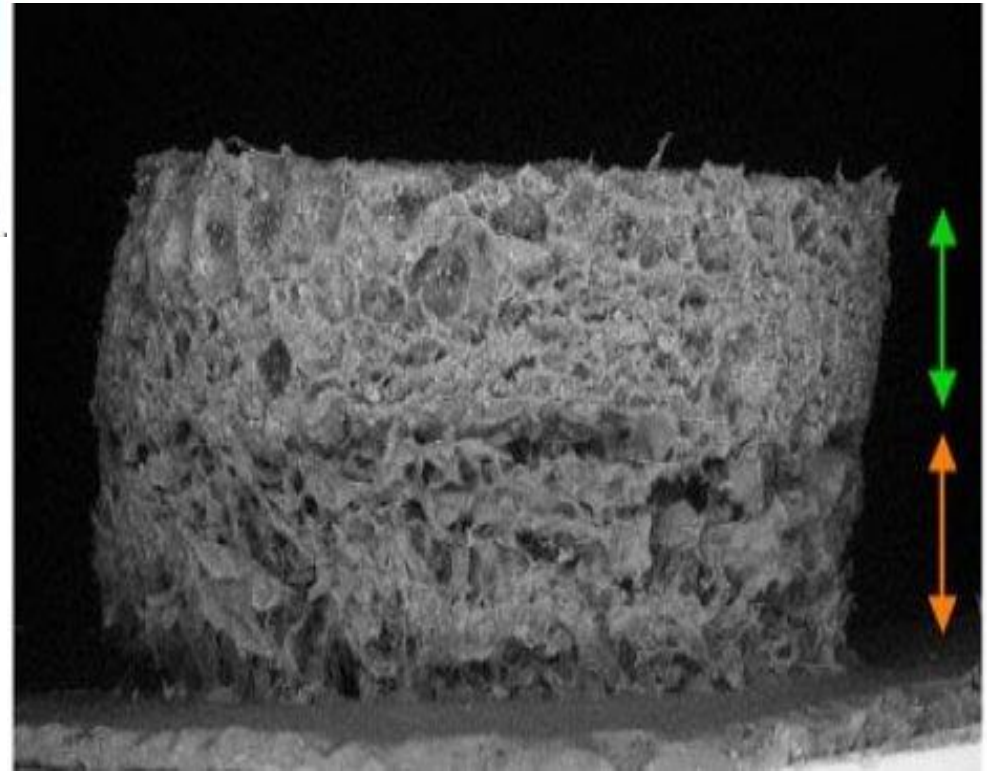
Tissue Engineering / Regenerative medicine



Tissue Engineering is the study of the growth of new connective tissues, or organs, from cells and scaffolds in order to produce a fully functional organ for implantation back into the donor host

Tissue Engineering / Regenerative medicine

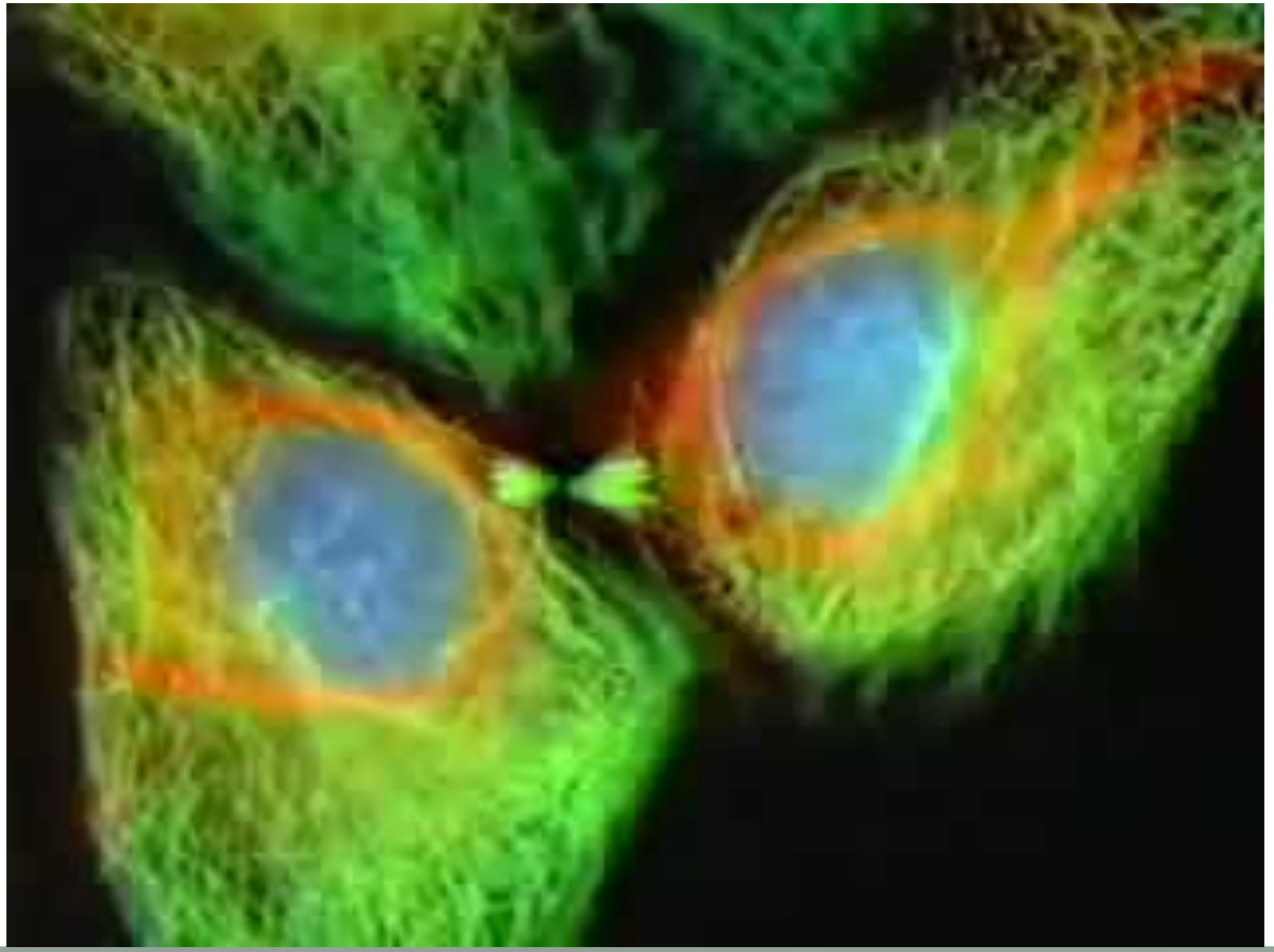




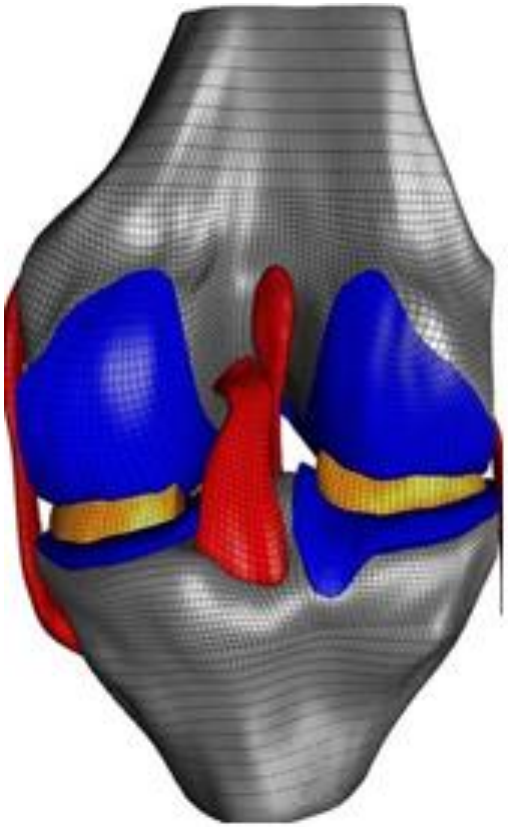
Tissue Engineering / Regenerative medicine

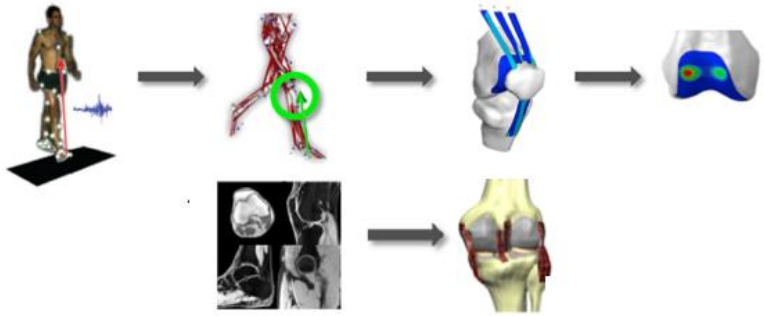
Source: VCU Life Sciences

MOV02-Tissue Engineering



Why/how and what to model in biomechanics of movement





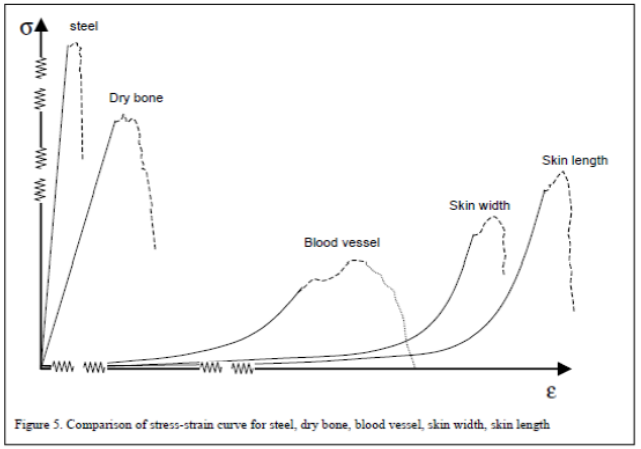
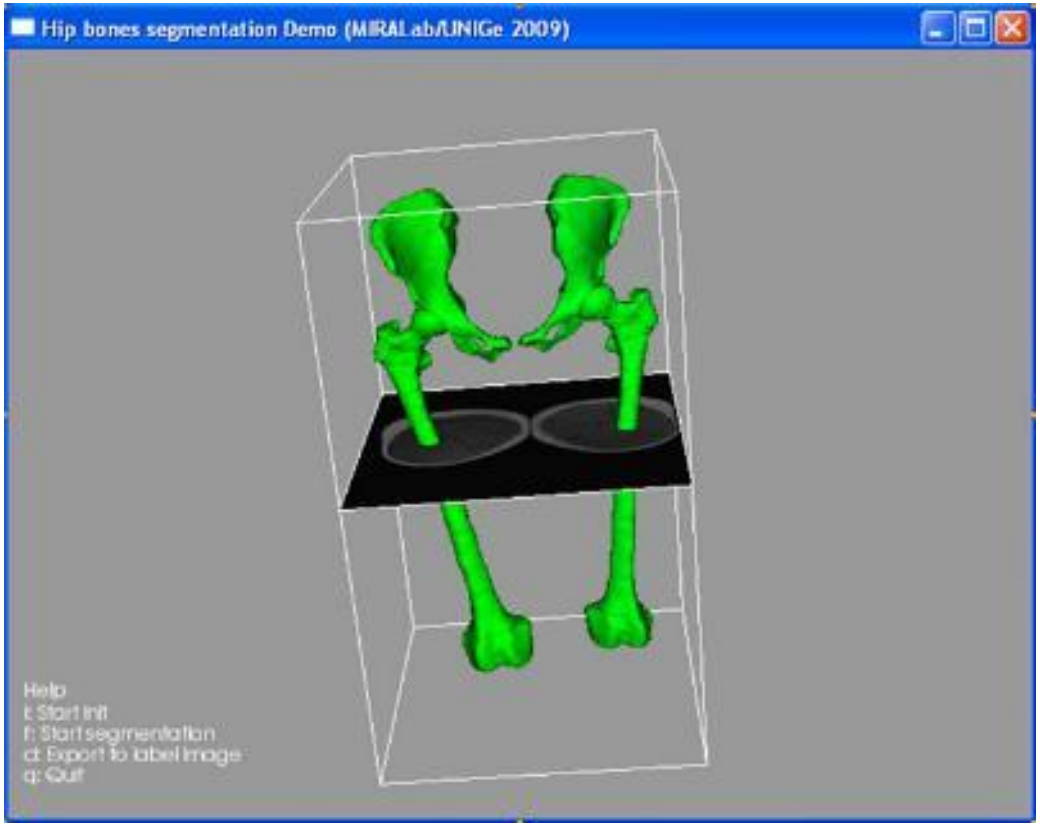
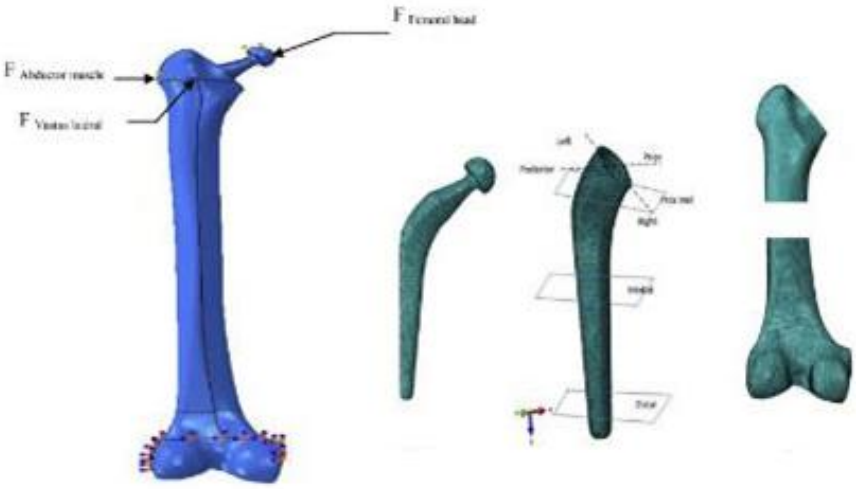


Figure 5. Comparison of stress-strain curve for steel, dry bone, blood vessel, skin width, skin length

Implant fitting and FEM study on hip prosthesis





Exams?

TBD

- We will have mandatory homeworks during the semester

- If „significant“ work has been carried out, we have no exams (similar to the „Medical Device“ course)

Questions?

Exams?

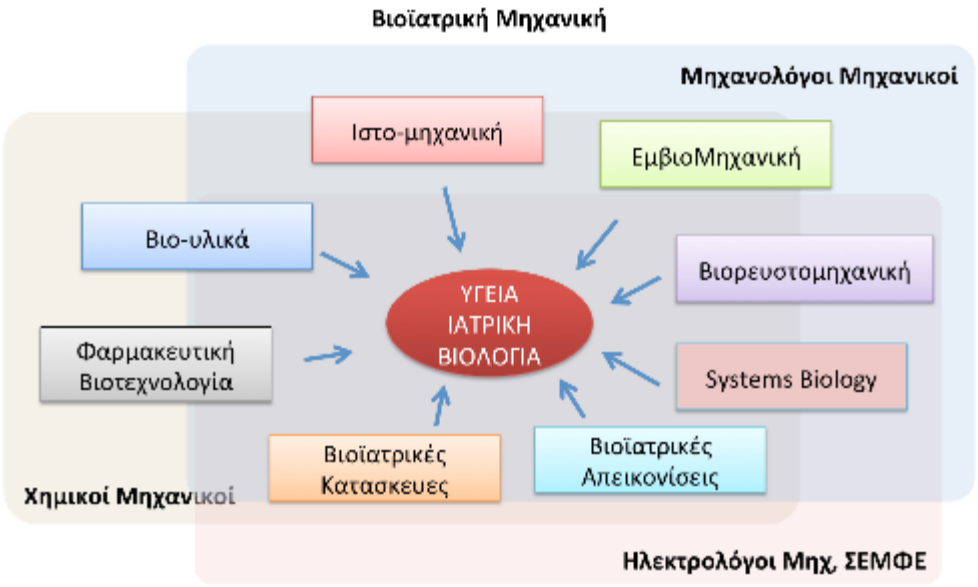
- Mandatory Homeworks

Conclusions

1. **Biomedical Engineering:** The most interdisciplinary field

1. The more you learn the different field, the better you are

3. The more you stay in your comfort zone, less opportunities arise



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